5. [illegible]

MOTOR VEHICLES
AND THEIR ENGINES

A Practical Handbook on the
CARE, REPAIR AND MANAGEMENT
OF
MOTOR TRUCKS AND AUTOMOBILES
for Owners, Chauffeurs, Garagemen and Schools

BY
EDWARD S. FRASER
American Bosch Magneto Corporation Formerly, Captain C. A., U. S. A.
Instructor Motor Transportation Course, Coast Artillery School

AND
RALPH B. JONES
Late Captain C. A., U. S. A.
Instructor Motor Transportation Course, Coast Artillery School

---

SECOND EDITION, REVISED AND ENLARGED

---

319 ILLUSTRATIONS

NEW YORK
D. VAN NOSTRAND COMPANY
EIGHT WARREN STREET
1922

PRINTED IN THE UNITED STATES OF AMERICA

PREFACE TO SECOND EDITION

The generous reception accorded the first edition of this book which is reflected in the sale of over fifteen thousand copies in a short time has encouraged the publication of this new and enlarged issue.

This revision afforded the opportunity of thoroughly modernizing the old material and of introducing much new matter descriptive of the many mechanical improvements developed since 1920. Many of the chapters have been entirely rewritten, a large number of new illustrations have been added and descriptions of a number of obsolete types of machinery eliminated. The few discussions of comparatively obsolete devices that have been retained, are given as a guide to theory rather than to practice.

The character and treatment of the subject has been carefully maintained, and it is felt that the book still contains all the information necessary to teach the proper operation and care of motor vehicles, presented in a comparatively small space.

Thanks are due to the various manufacturers who so kindly supplied cuts.

THE PUBLISHERS

August, 1922

PREFACE TO FIRST EDITION

The following pages represent the result of an attempt to collect in a comparatively small book such elementary, theoretical, and practical information as will assist in the operation, upkeep, and adjustment of motor vehicles. This book was written with a three-fold purpose; as a guide for the personal instruction of the car owner, as a handbook for chauffeurs, garages, and repairmen, and as a textbook for Automobile Schools. The simplest language has been used and technicalities have been reduced to a minimum. The fundamentals of gas motor operation, as well as the care and operation of the principal accessories of the motor vehicles concerned, are discussed in detail and at greater length than is the usual practice.

To obtain the maximum economy, efficiency, and life of the apparatus the last four chapters of the book should be studied. These chapters are the result of the authors' observations and experience with the great number of trucks, tractors, automobiles, and motor-cycles operating under their supervision.

This book is the outgrowth of the authors' former volume "Motor Transportation for Heavy Artillery," which was prepared for use as a textbook in the Coast Artillery School's course in the subject. The valuable experience gained in connection with their work as instructors in this school has been embodied in this second edition so that the book contains all the information necessary properly to operate and care for motor vehicles.

The authors wish to express their indebtedness to the Norman W. Henley Publishing Company for permission to use figures 6, 7, 46, 257, 279, 288, 294, 302, 304, 305, 308, and 310 from Pagé's "Modern Gasolene Automobile."

April, 1920 THE AUTHORS.

CONTENTS

MOTOR VEHICLES
AND THEIR ENGINES

CHAPTER I

THE GAS ENGINE

The term " Gas Engine " is commonly used to designate all types of internal combustion engines regardless of whether they operate on gas or liquid fuel. Liquid fuel is almost universally used in engines adapted for motor transportation. Gasoline is the most commonly used liquid fuel. Kerosene, alcohol, benzol, and fuel oil are used in internal combustion engines but in general their use is confined to engines of the stationary type.

In the internal combustion engine, the fuel is introduced into the cylinder in a combustible mixture and is there ignited. This type of engine is divided into two classes: that in which the combustion takes place gradually, and that in which the combustion takes place almost instantaneously.

The Diesel engine comes under the class in which the combustion is gradual. The liquid fuel is gradually injected into the cylinder which contains only air under high pressure. This air is compressed to such a degree that a temperature far above the ignition point of the fuel is obtained. This causes the fuel to ignite as it is injected into the combustion space. Complete but gradual combustion is obtained in this manner. Engines of this type are not suitable for motor-propelled vehicles, largely because of their lack of flexibility.

In the gasoline engine the fuel is burned almost instantaneously. The air is mixed with the fuel outside of the combustion space (Fig. 1) and the resulting combustible mixture is drawn into the cylinder where it is ignited under compression by some outside source of heat, the electric spark being the one universally adopted.

Combustion or burning is always accompanied by the production of heat. The temperature produced depends upon the rapidity and completeness of the combustion. The faster the burning the higher the maximum temperature produced. A slow burning fuel produces a more uniform temperature, but not as high as that produced by a fuel burning almost instantaneously.

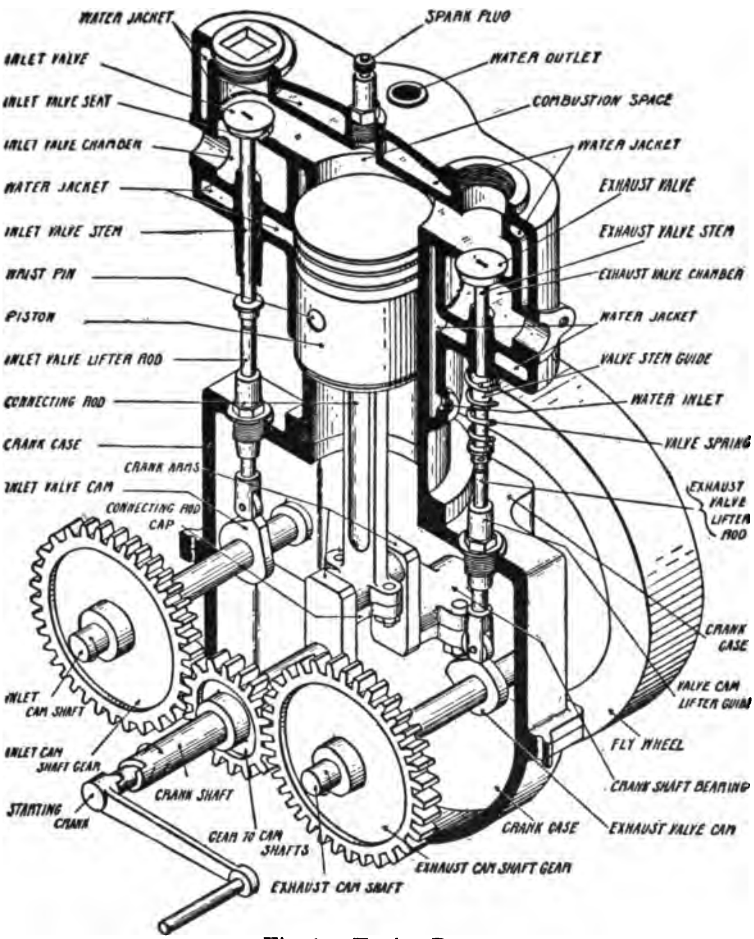


Fig. 1 — Engine Parts

Working Parts:

- Pistons
  - Piston rings
  - Wrist pins
- Connecting rods
  - Connecting rod caps
  - Shims
  - Connecting rod bearings
- Crank shaft
  - Gear to cam shaft
  - Crank arms
  - Crank pins
  - Journal
  - Flywheel.

Valve Mechanism:

- Cam shaft
  - Cam shaft gears
  - Inlet cams
  - Exhaust cams
- Push rods (lifter rods or tappets)
  - Roller or mushroom head
  - Adjusting nuts
- Valves
  - Valve stem
  - Valve spring
  - Valve head
  - Valve Clearance

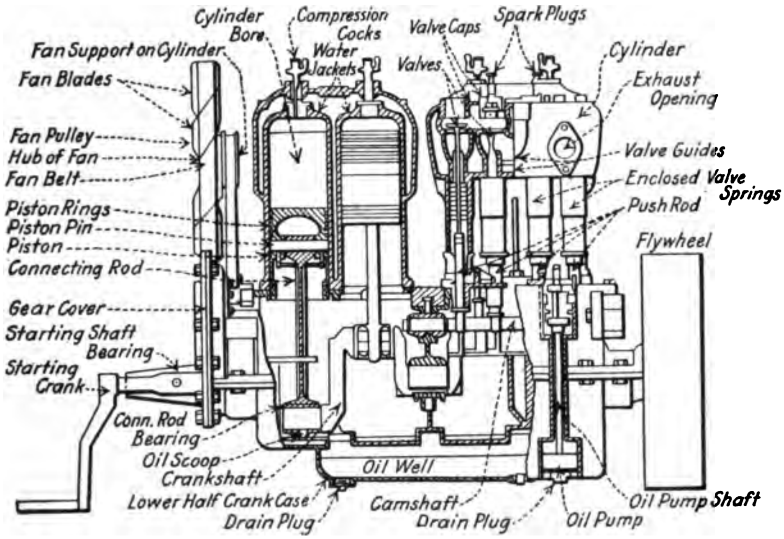


Fig. 2 — Sectional view of typical four-stroke cycle, four-cylinder motor truck engine, showing important internal parts and their relation to each other.

STATIONARY PARTS:
- Cylinder casting
  - Water jacket
  - Inlet ports
  - Exhaust ports
  - Valve seats
  - Cylinder head
  - Combustion space
- Crank case
  - Upper half
  - Lower half
  - Lifter guides
  - Main bearings
  - Cam shaft bearings
  - Oil reservoir
  - Oil pump
  - Float
  - Gear cover
  - Breather tube

ACCESSORIES:
- Inlet manifold
- Exhaust manifold
- Fan assembly
  - Fan
  - Pulley
  - Belt
  - Bracket
- Starting crank
- Valve caps
- Spark plugs
- Compression cocks (priming cocks)
- Water pumps
- Magneto or timer-distributor
- Carburetor

When gases and most metals are heated they expand, some expanding more than others. Gases expand more than metals for a given amount of heat. A definite increase of temperature will cause a gas to expand a certain amount and as the heat is increased the expansion increases in proportion. When the mixture in the cylinder is burned, the resulting heat causes the gases to expand, the amount of this expansion depending upon the temperature.

When a gas contained in a closed vessel is heated its expansion exerts a pressure equally in all directions. This condition exists in the cylinder of an internal combustion engine after combustion has taken place. The resulting pressure is exerted on the cylinder walls and piston. The piston, being movable, under the force of the expanding gases, moves outward to the full limit of its stroke.

The energy resulting from this expansion must now be transformed into useful work. In order to accomplish this, a construction such as shown in Fig. 3 is used.

The force exerted on the piston *K* is transmitted through the connecting rod *E* to the crank shaft *H* which is made to revolve, turning through one half of a revolution as the piston moves outward. Attached to the crank shaft is a flywheel, which stores up energy and its momentum carries the piston through the balance of its motion until it receives another power impulse. In this way the reciprocating motion of the piston is transformed into a rotary motion at the crank shaft.

The operation of the gasoline engine, as already shown, depends upon the production of heat in the cylinder caused by burning the

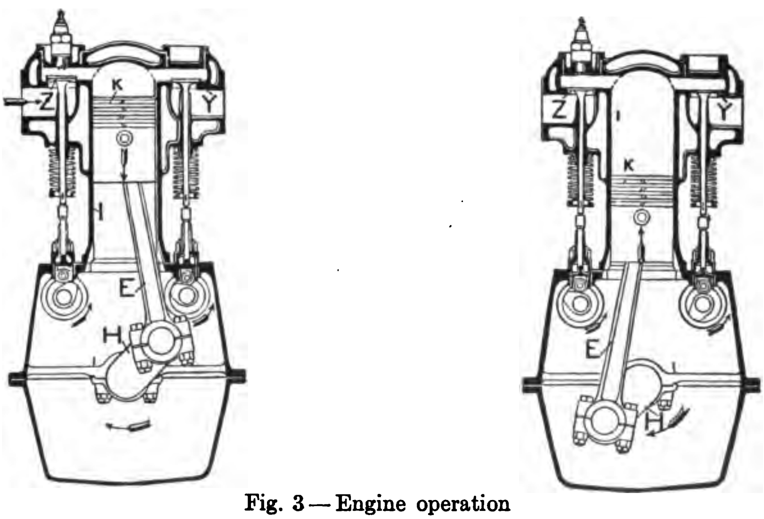


Fig. 3 — Engine operation

fuel. A given amount of fuel will produce a certain amount of heat when completely burned. However, the total heat value of the fuel cannot be utilized because there are certain losses which must always occur even in the best designed engine. Badly worn engines, imperfect carburetion, and faulty ignition will add to the necessary losses and decrease the percentage of energy actually available for useful work.

The highest thermal efficiency attained in the best types of large stationary internal combustion engines (Diesel) is about 35% while few automobile engines ever exceed 20%. The diagram (Fig. 4)

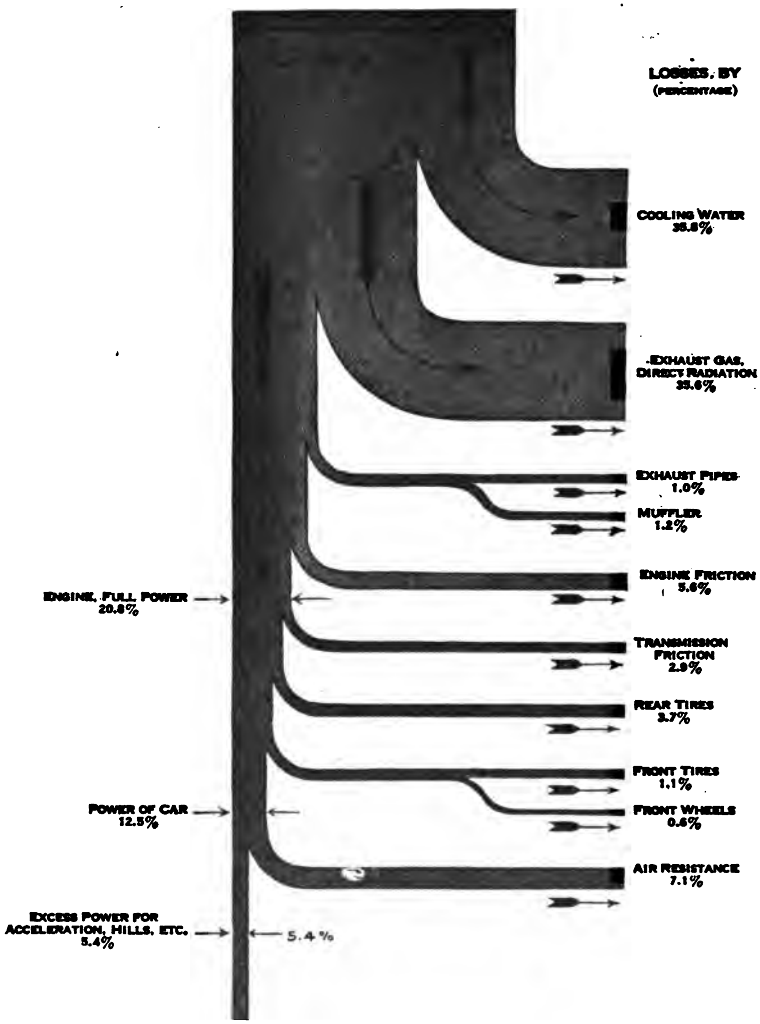


Fig. 4 — Energy diagram

shows the dispersion of energy from fuel as it passes through the engine of a high class touring car traveling at a speed of 40 miles per hour on direct drive.

Referring to Fig. 4, it will be seen that a certain amount of the heat is absorbed by the cooling system. Also a considerable amount

of heat is lost in the exhaust gases. Nearly 70% of the total fuel value is lost in this way and this loss cannot be materially reduced below this amount. The loss due to engine friction will vary considerably with the design and condition of the engine. The point indicated as "Engine Full Power" represents the amount of energy remaining for useful work. When this energy is applied to driving an automobile, it is consumed as shown in the diagram. This leaves but a small amount of reserve energy, which will be decreased as the speed of the machine is increased. Every design of engine and car of course has a different energy diagram corresponding to the degree of efficiency attained at different speed and loads.

Engines of all kinds are rated in horse-power — the measure of the rate at which they can do work. One horse-power represents 33,000 foot-pounds of work per minute. There are two ways of measuring engine power. The power developed by the expansion of the gases in the cylinder can be determined, in which case the **indicated horse-power** is obtained. By means of a Prony Brake or Dynamometer, the power which the engine actually delivers can be measured and this is called the **brake horse-power.** The brake horse-power of an automobile engine will usually be from 70% to 85% of its indicated horse-power, the losses being energy consumed in friction and other causes in the engine mechanism. However, in obtaining the horse-power of an engine, formulae are used based on the indicated horse-power assuming certain standard conditions. The horse-power obtained in this manner is often inconsistent with the actual horse-power developed on test.

There are a number of quick rules for estimating the power of engines according to their cylinder dimensions and the piston speed. The one most used for four-cycle engines is given below. The simplest formula is that of the Society of Automotive Engineers:

$$\text{H. P.} = \frac{D^2N}{2.5}$$

The formula for finding the indicated horse-power of an engine is:

$$\text{I. H. P. (for 1 Cylinder)} = \frac{P.A.S.}{33{,}000 \times 4}$$

Where P = mean effective pressure in pounds per square inch.
A = piston area in square inches.
S = piston speed in feet per minute.

Where the engine has more than one cylinder, the result obtained from this formula must be multiplied by the number of cylinders.

The brake horse-power is obtained by multiplying by the mechanical efficiency of the engine. The complete equation for brake horse-power is:

$$\text{B. H. P.} = \frac{P. A. S. N. E.}{33{,}000 \times 4}$$

Where N = number of cylinders.
E = mechanical efficiency.

Assuming a mean effective pressure of 90 pounds per square inch, a piston speed of 1,000 feet per minute, and a mechanical efficiency of 75% and substituting these values in the formula for brake horse-power, the following value is obtained:

$$\text{B. H. P.} = \frac{D^2N}{2.489} \text{ or approximately } \frac{D^2N}{2.5}$$

Where D = diameter of piston in inches.

This is the S. A. E. formula for four-cycle engines

For two-cycle engines this becomes:

$$\text{B. H. P.} = \frac{D^2N}{1.5}$$

CHAPTER II

PRINCIPLES OF TWO- AND FOUR-CYCLE ENGINES

In order that the operation of the gas engine be continuous, a certain series of events called the cycle must take place which are repeated over and over in the same regular order. To clearly understand the events that compose the cycle of an engine, its operation will be compared to the operation of the old style muzzle-loading cannon, which is the simplest form of internal combustion engine.

Referring to Fig. 5, the first step necessary to fire the cannon is inserting the charge; the corresponding step in the gas engine is the **admission** of the charge. The second step is ramming the projectile and powder; the corresponding step in the gas engine is the **compression** of the charge. The third step is lighting the fuse; the corresponding step in the gas engine is the **ignition** of the charge. The fourth step is burning the powder and the fifth step expansion of the gases of combustion due to the heat produced which forces the projectile out of the cannon. The corresponding steps in the gas engine are the **combustion** of the charge and **expansion** of the gases. The sixth step in the operation of the cannon is the escape of the burned gases after the projectile has left the muzzle; the corresponding step in the gas engine is the subsequent **exhaust** of the products of combustion. The cannon is now ready to be fired again and the engine to continue its operation.

The steps comprising the cycle of operation of the gas engine may be summarized as follows:

1. Admission of the charge.
2. Compression of the charge.
3. Ignition of the charge.
4. Combustion of the charge.
5. Expansion of the gases.
6. Exhaust of the gases.

In the operation of a gas engine the number of strokes required to complete the cycle varies with the type of engine. In the type almost universally used for motor vehicles the cycle is extended through four strokes of the piston or two revolutions of the crank

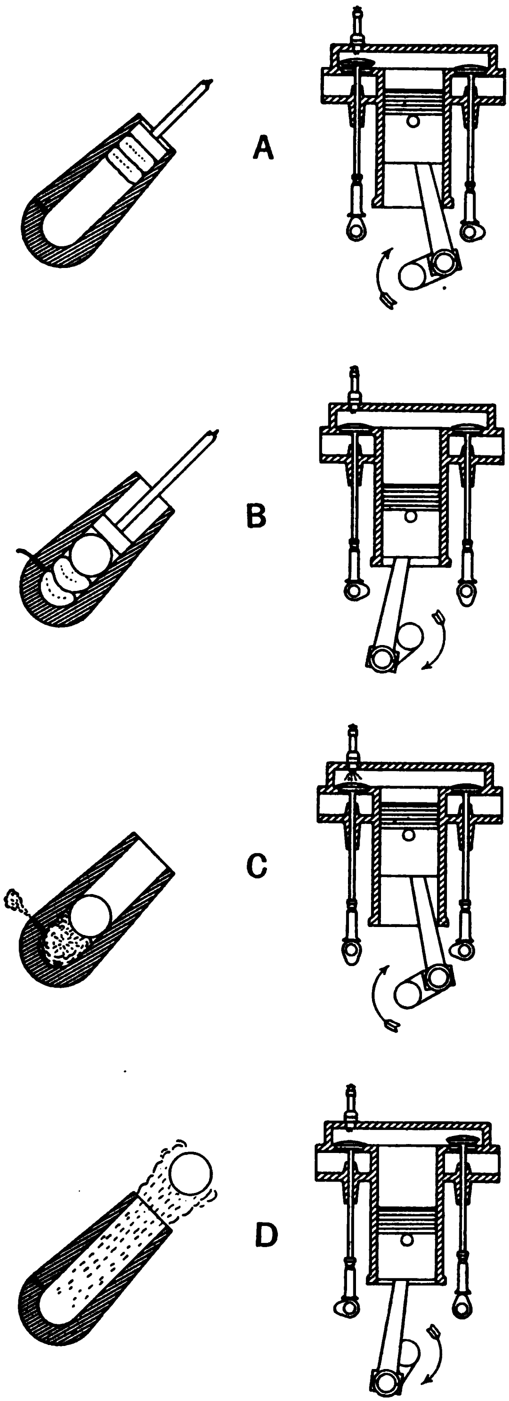


Fig. 5 — Operation of cannon and engine compared

shaft and is therefore called a four-cycle engine. In a few instances the cycle is completed in two strokes of the piston or one revolution of the crank shaft and is therefore called a two-cycle engine.

Four-Cycle Engines

In the four-cycle engine, the four strokes are named suction, compression, power, and exhaust in accordance with the operations of the cycle which occur during each particular stroke.

Suction Stroke.—During this stroke (Fig. 5-A) the piston is moved outward by the crank shaft which is either revolved by the momentum of the flywheel or some external starting force. This movement of the piston increases the size of the combustion space, thereby reducing the pressure in it and the higher pressure of the atmosphere outside, forces fresh mixture into the combustion space through the open inlet valve.

Compression Stroke.— The compression, ignition, and most of the combustion of the charge takes place during the next inward stroke of the piston. The time elapsed between the mixing of the liquid gasoline and air and its admission into the cylinder is too brief to secure a perfect combustible mixture. What passes into the cylinder consists of air, liquid gasoline, and a more or less perfect mixture of the two. The combustion of this mixture would be slow and incomplete resulting in a loss of power and a waste of fuel. In order to obtain a homogeneous mixture, advantage is taken of the heat produced by compression. This renders the gasoline more volatile, while the compression forces it into intimate combination with the air. Even then a perfect mixture may not result for the air and gasoline vapor instead of being thoroughly combined may be in layers. The combustion will then be slow and uneven. When the mixture of air and gasoline vapor are properly proportioned, this difficulty is seldom encountered. The mixture is ignited while under compression and combustion is practically completed at top dead center.

Power Stroke. —The expansion of the gases due to the heat of combustion exerts a pressure in the cylinder and on the piston. Under this impulse it moves outward.

Exhaust Stroke. — When the exhaust valve is opened, the greater part of the burned gases escape due to their own expansion. The inward movement of the piston pushes the remaining gases out of the open exhaust valve. The space between the cylinder head and the piston, when it is at its inmost point, is called the clearance and will be filled with the remaining exhaust gases. These will dilute the fresh incoming charge.

Thus it is seen that in this type of engine four strokes of the piston are required to complete the cycle.

Two-cycle Engines

The two-cycle type of gasoline engine differs from the four-cycle type just described in that the six events composing the cycle are performed during two strokes of the piston or one revolution of the crank shaft. Power is developed during every outward stroke of the piston instead of alternate outward strokes.

In order that this result may be attained, the construction of the engine is changed. As shown in Fig. 6, the crank case is utilized as

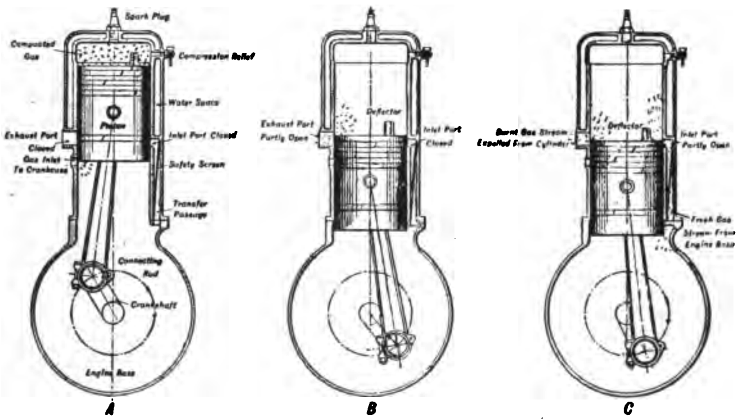


Fig. 6 — Three-port two-cycle engine

a receiver for the mixture before it passes to the combustion space. The valves are replaced by ports, which are openings into the combustion space. These are covered and uncovered by the piston as it slides in the cylinder. The gas inlet port to the crank case is uncovered when the piston is at the inmost point of its stroke admitting the mixture to the crank case. This is air tight and must have a separate compartment for each cylinder. The exhaust port and the intake port are uncovered when the piston is at the outmost point of its stroke. The exhaust port opens first, which permits the burned gases to escape after combustion has taken place. The intake port opens shortly after the opening of the exhaust port and permits a fresh charge to pass from the crank case to the combustion space.

During an inward stroke, the pressure in the crank case is reduced as the piston moves inward and a fresh mixture is forced into

it by the higher atmospheric pressure as soon as the gas inlet is uncovered. This port is covered when the piston makes an outward stroke and the mixture, not being able to escape, is compressed. The tendency of the gas to expand causes it to flow to the combustion space when the inlet port is uncovered, and in entering, it strikes a deflecting plate on the piston. This deflects it to the top of the combustion space instead of allowing it to rush across the cylinder and out of the open exhaust port. The inward stroke of the piston covers these two ports and compresses the mixture, ignition occurring in the regular manner. The pressure developed by the combustion drives the piston outward. As soon as the exhaust port is uncovered, which is slightly before the uncovering of the inlet port, the gases, which are still expanding, begin to escape. They

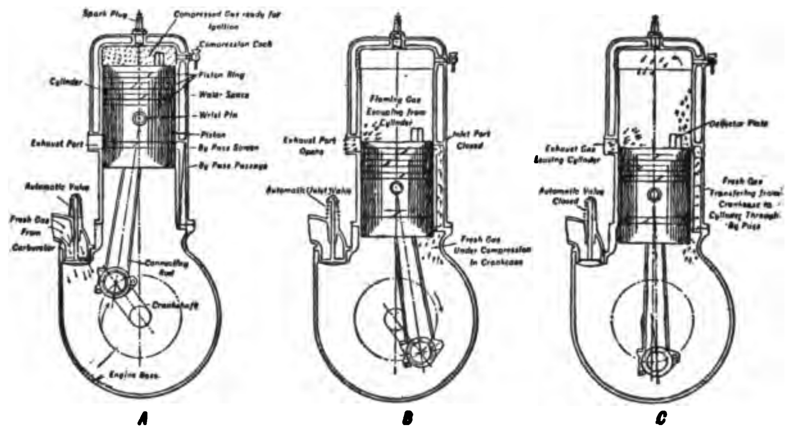


Fig. 7 — Two-port two-cycle engine

are further expelled by the fresh charge that enters and drives them before it. Thus the six events of the cycle are performed during an inward and an outward stroke of the piston. On the lower side of the piston a charge of fresh mixture is drawn into the crank case and forced into the combustion space where it is compressed, ignited, and burned.

The type of engine just explained is known as the three-port construction of the two-cycle engine. There is also a two-port construction of two-cycle engine. This type of engine differs from the three-port in that the inlet port to the crank case is replaced by a check valve as shown in Fig. 7. When the pressure in the crank case is reduced due to the piston moving inward, the higher atmospheric pressure opens the valve and forces a fresh mixture into the crank case. The valve is closed by the action of the spring at all

other times and is further assisted in closing by compression in the crank case. The operation of this engine is identical in all other respects with the three-port construction.

In all two-cycle engines a screen is placed in the bypass. The object of this is to prevent any possibility of the incoming charge being ignited by the exhaust gases thus causing a back-fire into the crank case.

At slow speeds, two-cycle engines have advantages over the four-cycle in having a power impulse every revolution of the crank shaft and in not having valves and valve mechanism with their weight and possibility of giving trouble. This simplicity makes the two-cycle engine popular for motor boats, where slow and constant speeds are desired. For higher and changing speeds these advantages are outweighed by disadvantages that show little sign of being overcome.

With the engine running at high speed, the ports are open for only a brief period during each stroke, and the faster the engine runs, the shorter will be the period during which the gases may enter or leave the combustion space. The inefficiency of the two-cycle engines as compared with engines of the four-cycle type is due entirely to the fact that the burned gases have not sufficient time in which to escape from the combustion space, nor the fresh charge time to enter. The fresh charge that does enter is incomplete and contaminated by the portion of the burned gases that have not been able to escape. This results in the "choking up" of the engine, and in the production of lower power than the dimensions and weight of the engine warrant.

Automobile engineers agree that the four-cycle engine is better for automobile work. It has been developed to a greater degree than the two-cycle and it is easier to keep adjusted and in good running condition. Though the two-cycle engine is undoubtedly the simplest form, it is liable to be erratic in operation and it is sometimes difficult to locate the trouble definitely. The following advantages are claimed for the two-cycle engine over the four-cycle: (1) absence of poppet valves with their springs, push rods, cam shafts, etc.; (2) fewer parts; (3) better turning effect with the same number of cylinders. Offsetting these, the four-cycle engine has the following advantages over the two-cycle: (1) greater fuel economy, (2) greater flexibility. These advantages far over-balance the advantages of the two-cycle over the four-cycle engine and for that reason the two-cycle engine is very rarely used for automobile propulsion.

CHAPTER III

TIMING

As explained in the operation of the four-cycle engine, the inlet valve is opened during the suction stroke and the exhaust valve is opened during the exhaust stroke. In this chapter will be shown the exact time at which the valves open and close with reference to the position of the piston. In outlining the timing of the valves, the reason for each operation of the valve will be explained.

During the inlet stroke, the inlet valve must be opened to admit the charge. The charge is forced into the cylinder due to the pressure being reduced as the piston moves outward. If the inlet valve were opened at top dead center, the gases would not be forced into the cylinder until the piston had moved out sufficiently to cause a decrease in pressure and the velocity of the incoming gases for some time would be slow. In order to prevent this, the inlet valve remains closed for a certain number of degrees during the downward movement of the piston. This causes a sufficient decrease in pressure to allow the gases to be forced in with a certain amount of initial velocity. Most manufacturers have adopted this practice as the cylinder will be filled more rapidly.

The rapid decrease in pressure in the cylinder due to the outward movement of the piston causes the gases to rush in and fill up the space back of the piston. If the piston moves slowly, the mixture will be able to enter fast enough to keep the pressure in the combustion space equal to that outside. At the high speed at which a gasoline engine runs, the piston will reach the end of its stroke before a complete charge has had time to enter through the small inlet valve opening. Therefore the pressure in the combustion space will still be below that of the atmosphere. If the inlet valve closed at this point so that no more mixture could enter, the combustion of the partial charge would result in a lower pressure than would be possible with a full charge. The inlet valve should therefore remain open until the piston reaches a point in its next inward stroke at which the pressure in the cylinder equals that outside. The piston moving inward diminishes the space in the cylinder and compresses the gas ahead of it. When under compression, the gas is ready to be ignited and burned.

The combustion of the inflammable mixture produces a certain amount of heat. The more rapid and complete this combustion, the greater and more sudden will be the rise in pressure. The pressure will be greater when the mixture is contained in a small space than when in a large space. As the combustion space is smallest when the piston is at its inmost point, the greatest pressure will be obtained if combustion is completed at this point. If the combustion of the mixture were instantaneous, it would be ignited at this point. But even though very rapid, it burns slowly enough to make necessary the ignition of the mixture before the end of the stroke. The combustion will then be complete as the piston comes into position to move outward. The instant at which the mixture must be ignited in order to produce this result depends on the speed of the piston. The interval between the ignition of a good mixture and its complete combustion does not vary to any great extent. When the piston is moving slowly, the mixture may be ignited toward the end of the compression stroke, for there will be sufficient time for complete combustion by the time the stroke is ended. When moving at high speed, ignition must occur much earlier in the stroke, as otherwise the piston will have completed the compression stroke and begun to move outward on the power stroke before the mixture is entirely burned. The instant at which ignition occurs also depends on the mixture that is used, since this makes a difference in the rapidity with which it burns. The better the quality of the mixture, the faster and more completely it will burn and ignition may occur later in the stroke than would be possible with a mixture of poorer quality. The instant at which ignition occurs may be controlled by causing the spark to take place earlier or later, this being controlled by the driver.

When ignition occurs early in the compression stroke, the spark is said to be advanced. A retarded spark takes place when the compression stroke is more nearly complete.

If the spark is advanced too much, combustion will be complete before the piston has reached the end of the compression stroke. It will then be necessary to force the piston inward against a resultant pressure by the momentum of the flywheel, in order that it may get into position to move outward on the power stroke. In such a case, the momentum may not be sufficient to overcome the pressure and the piston will be brought to a stop.

A retarded spark often results in the complete combustion of the mixture after the piston has begun to move outward on the power stroke. The pressure will then be reduced because combustion takes place in a larger space, the piston consequently being moved with

less force. If the spark is still further retarded, the combustion will not be completed by the time exhaust begins. The heat from only a portion of the mixture will then be utilized because the gases will still be burning as they are forced out of the cylinder.

The position at which the spark occurs should be governed by the speed of the engine. The low pressure that results from a retarded spark moves the piston at low speed, while the high pressure from an advanced spark drives the piston outward with more force and greater velocity.

While high compression of the charge improves its quality and results in combustion being more rapid and complete, it has limits, and if carried too far the heat generated by the compression will be sufficient to ignite the mixture. This would have a bad effect on the operation of the engine, for the pressure would then be produced at the wrong point in the stroke, retarding instead of assisting the revolution of the crank shaft.

As the piston is forced outward by the expanding gases, it has been found necessary to open the exhaust valve before the piston reaches the end of its stroke. Even if this wastes some of the force of the expansion, it is amply compensated for by the freedom afforded the piston in commencing the exhaust stroke. By opening the exhaust valve, before the piston reaches the end of its power stroke, the gases will have an outlet for expansion and begin to rush out of their own accord. This removes the greater part of the burned gases, reducing the amount of work to be done by the piston on its return stroke. Obviously it would be wrong to keep the exhaust valve closed up to the very moment when the piston is about to move inward. When commencing the exhaust stroke, the piston would be confronted for an instant with the force which had just driven it down and until the valve was wide open there would be a considerable loss of power. If the exhaust valve opens too early, there will be a waste of power because the gases exhausted could still have exerted a pressure on the piston. During the next inward stroke, the remaining gases are forced out of the open exhaust valve as the pressure in the cylinder exceeds that in the exhaust manifold. This causes a slight compression of the gases ahead of the piston and when it reaches its inmost position there will be a certain amount of compressed exhaust gases in the clearance space.

If the exhaust valve is closed at this point, a portion of these gases will still be retained in the cylinder. The best results are obtained, not by closing the exhaust valve at the end of the exhaust stroke, but at a short time after the piston has begun to move outward. It would appear that this would result in drawing the ex-

haust gases back into the cylinder. However, this is governed by two conditions: first, the gases under compression exceed the pressure in the exhaust manifold and will continue to flow out due to this difference in pressure; second, the piston while at the top of the stroke moves but very little for 10 to 15 degrees movement of the crank shaft. This does not materially increase the combustion space.

It will be seen that this is true by referring to Fig. 8. When the crank arms are in a position as shown at *A*, for a certain number of degrees movement of the crank shaft, the piston will move upward for a certain distance. When the crank arms are at point *B*, for the same number of degrees movement of the crank shaft, the distance moved by the piston will be less. When the crank arms are at point *C*, for the same number of degrees there is very little up-

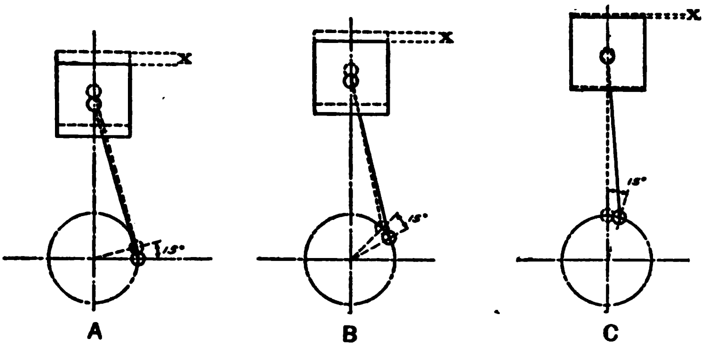


Fig. 8 — Rock of piston

ward movement of the piston. Between certain points it can be seen that there is practically no motion of the piston which is called the " rock of the piston." This is usually the amount that the exhaust valve is left open after top dead center.

Diagrams showing the exact timing of the valves on several engines are shown in Figs. 9 to 12, inclusive. From these diagrams, comparisons may be made as to the time the valves open and close in different designs of engine.

Referring to the valve timing diagrams, it will be seen that the point at which the inlet valve opens is approximately the same on these four standard engines which are designed to run at different speeds and for different kinds of work. On practically all engines, the inlet valves open approximately 11 degrees after top dead center.

The point at which an inlet valve closes depends upon a great many conditions, the principal ones being the maximum speed for which the engine is designed and the size and location of the valves.

The average point for closing the inlet valve is about 35 degrees after bottom dead center. The valve closes later on high speed engines and earlier on slow speed engines.

The point at which the exhaust valve opens also varies considerably and depends upon the same conditions as the closing of the

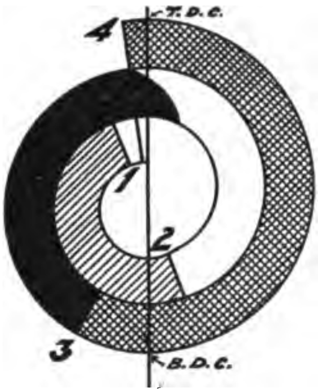


Fig. 9 — Holt

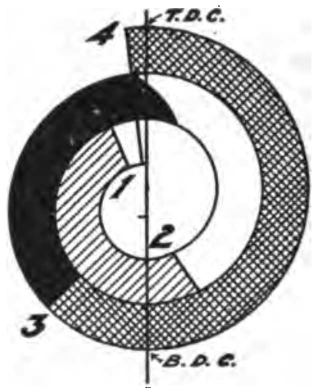


Fig. 10 — Dodge

	Holt	Dodge
1. Inlet valve opens	10° after T. D. C.	10° after T. D. C.
2. Inlet valve closes	10° after B. D. C.	35° after B. D. C.
3. Exhaust valve opens	30° before B. D. C.	45° before B. D. C.
4. Exhaust valve closes	5° after T. D. C.	8° after T. D. C.

Fig. 11 — White

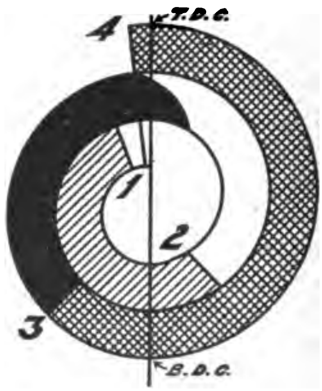


Fig. 12 — F. W. D.

	White	F. W. D.
1. Inlet valve opens	10° after T. D. C.	15° after T. D. C.
2. Inlet valve closes	40° after B. D. C.	45° after B. D. C.
3. Exhaust valve opens	40° before B. D. C.	45° before D. D. C.
4. Exhaust valve closes	8° after T. D. C.	10° after T. D. C.

The above diagrams each represent the two revolutions of the crank shaft necessary to complete one cycle.

inlet valve. The average point for opening the exhaust valve is 45 degrees before bottom dead center. It will be earlier on high speed engines and later on slow speed engines.

The exhaust valves of the engines represented in the timing diagrams all close at approximately the same point. This is true of practically all types of engines, the average point for closing the exhaust valve being 6 degrees after top dead center. This point is limited by the duration of the rock of the piston and hence cannot vary greatly.

Figure 13 shows a valve timing diagram made up from the average points at which the valves open and close on engines of American design. It is a good guide for the approximate timing of the valves of an engine in case the exact timing is not known. However, it must never be used for accurately setting the valves of any engine.

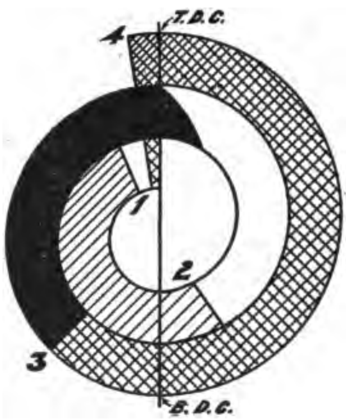


Fig. 13 — Valve Timing of average engine

1.	Inlet opens	11°	after T. D. C.
2.	Inlet closes	35°	after B. D. C.
3.	Exhaust opens	45°	before B. D. C.
4.	Exhaust closes	6°	after T. D. C.
	Suction	204°	
	Compression	145°	
	Power	135°	
	Exhaust	231°	

If for any reason it is necessary to disassemble the engine, the timing gears should be punched so as to indicate where they should mesh when they are again assembled in order to have the proper timing of the valves. If an engine is received with the flywheel unmarked, the first duty for the man in charge of the apparatus is to see that the flywheel is marked correctly in order to have some accurate method of checking up valve-timing and valve-clearance at all times. Marking the flywheel is a very simple matter and will eliminate endless trouble whenever any repairs are made to the engine where disassembling is necessary.

In case a crank shaft is offset from the center line of the cylinders, the exhaust valves will usually close at top dead center, as the rock of the piston at this point has been eliminated. The reason for such design is that when the maximum expansion occurs at top dead center, there will not be a direct downward thrust on the crank shaft and connecting rod bearings.

CHAPTER IV

ENGINE BALANCE AND FIRING ORDER

The term " engine balance " includes both power balance and mechanical balance of the engine. An engine has power balance when the power impulses occur at regular intervals in relation to the revolution of the crank shaft. In many types of engines the power impulses do not occur regularly and there is an uneven distribution of power. The power balance of various types of engines will be discussed in this chapter. An engine has mechanical balance when the moving parts are so arranged as to counterbalance in their operation and thereby reduce vibration.

The difficulty in constructing reciprocating engines is that the weight of the pistons and connecting rods in moving first one way and then the other, produces great vibration. The crank shaft in bringing these parts to a stop at the end of each stroke, is subjected to violent shocks which in time wear it loose in its bearings. With internal combustion engines, this vibration and the shock on the crank shaft are greatly increased by the intensity with which the pressure is exerted on the piston.

In a well-designed engine, the manufacturer is very careful to see that every piston and connecting rod is of identically the same

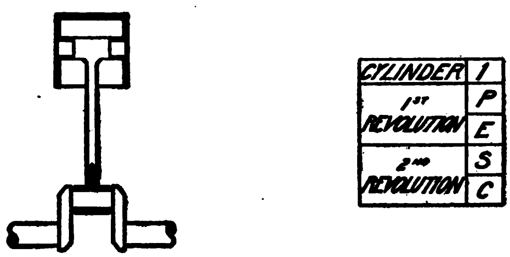


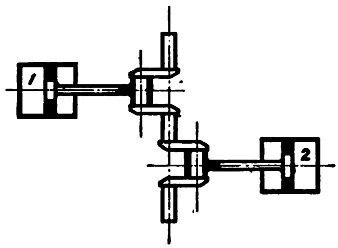
Fig. 14 — One-cylinder power balance chart

weight and that the flywheel and crank shaft have a perfect running balance. By this practice a considerable amount of the vibrations will be eliminated.

In a one-cylinder engine (Fig. 14) there is but one power impulse during two revolutions of the crank shaft. Therefore there will be an uneven distribution of power. Since there is but one piston and

connecting rod which reciprocate with no working parts to counterbalance their weight, the engine will not have mechanical balance. The engine can, however, be balanced to some extent by the use of counterweights attached to the crank shaft and also by the use of a flywheel so heavy that its momentum produces a comparatively steady movement. Fluctuations in the speed of the engine will cause vibration even under the most favorable conditions which makes the one-cylinder engine undesirable for motor vehicles.

In two-cylinder engines, the vibration may be reduced by arranging the parts so as to have the pistons move in opposite directions, thus counterbalancing each other. This is the plan of construction used in the horizontal double opposed engine (Fig 15).



CYLINDER	1	2
1ST REVOLUTION	P	S
	E	C
2ND REVOLUTION	S	P
	C	E

Fig. 15 — Two-cylinder opposed power balance chart

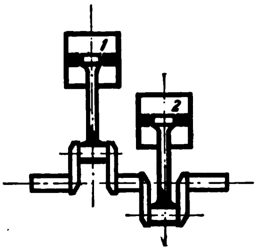
The cylinders are horizontal and arranged on opposite sides of a two-throw 180 degree crank shaft. That is, there are two pairs of crank arms projecting from opposite sides of the shaft so that they are one half a revolution apart. An engine of this construction has good mechanical balance.

To fully understand the power balance as shown in the table, the order in which the strokes of a four-cycle engine occur must be recalled. The two outward strokes are suction and power and the two inward strokes compression and exhaust. If piston number one is moving outward on power, then piston number two must be moving out on suction, and for the next half revolution or inward strokes of the pistons, number one piston will be exhausting the gases while number two piston is compressing the charge. During the second revolution of the crank shaft, number two piston will move outward on power while number one moves outward on suction and during the inward strokes of the pistons, number two is exhausting the burned gases while number one is compressing a fresh charge. In this way, one power impulse is obtained during each revolution of the crank shaft. This engine has both power balance and mechanical balance.

Two-cylinder engines are also built with vertical cylinders and are

classed according to the construction of their crank shafts. One has a 180 degree crank shaft which is identical with that used in the two-cylinder opposed engine. The other has a 300 degree crank shaft, which has both pairs of crank arms projecting from the same side of the shaft, so that the crank pins are in line.

In the two-cylinder 180 degree crank shaft construction (Fig. 16) number one piston is moving outward as number two piston is moving inward; in other words, the pistons move in opposite directions. An engine of this construction has good mechanical balance.



I

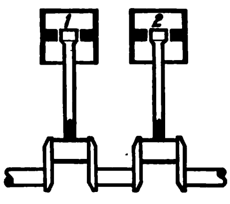
CYLINDER	1	2
1ST REVOLUTION	P	C
	E	P
2ND REVOLUTION	S	E
	C	S

II

CYLINDER	1	2
1ST REVOLUTION	P	E
	E	S
2ND REVOLUTION	S	C
	C	P

Fig. 16 — Two-cylinder 180 degree crank shaft power balance chart

If piston number one is moving outward on power, piston number two can be moving inward either on compression or exhaust. In table one, the power balance is worked out with piston number two moving inward on compression and it is clearly shown that both power impulses occur during the first revolution while there are no power impulses during the second revolution. In table two the power balance is worked out with piston number two moving inward on exhaust. This arrangement gives a power impulse at the beginning of the first revolution and at the end of the second, producing



CYLINDER	1	2
1ST REVOLUTION	P	S
	E	C
2ND REVOLUTION	S	P
	C	E

Fig. 17 — Two-cylinder 360 degree crank shaft power balance chart

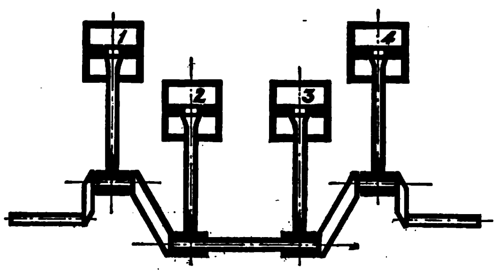
the same result as obtained in table one. In either case there is an irregular production of power which sets up strains in the engine which causes it to run unevenly. This results in poor power balance.

In the two-cylinder vertical engine with a 360 degree crank shaft, the pistons move up and down together causing bad mechanical balance (Fig. 17).

With this arrangement the application of power may be evenly distributed, for as number one piston moves outward on power, piston number two could move outward on either power or suction. There would be no advantage in having both cylinders firing at the same time, hence number two piston moves outward on suction. As shown in the table, during the first revolution, number one piston is on power and exhaust while number two piston is on suction and compression. During the second revolution number one piston is on suction and compression while number two piston is on power and exhaust. With this arrangement there is a power impulse at the beginning of each revolution of the crank shaft and the engine has power balance.

The defects of two-cylinder vertical engines with either design or crank shaft outweigh any possible advantage of that construction. The horizontal double opposed type with evenly occurring power impulses, mechanical balance, and simplicity of construction is frequently used on small trucks.

With a four-cylinder engine a 180 degree crank shaft is always used (Fig. 18). The crank arms for numbers one and four cylinders



I

CYLINDER	1	2	3	4
1ST REVOLUTION	P	E	C	S
	E	S	P	C
2ND REVOLUTION	S	C	E	P
	C	P	S	E

II

CYLINDER	1	2	3	4
1ST REVOLUTION	P	C	E	S
	E	P	S	C
2ND REVOLUTION	S	E	C	P
	C	S	P	E

Fig. 18 — Four-cylinder power balance chart

project in the same direction and the crank arms for numbers two and three cylinders project from the opposite side of the crank shaft. This arrangement is used in preference to having the cranks projecting alternately, that is, one and three to one side and two and four to the other, because greater vibration and strain on the crank shaft would result with this construction. The form of crank shaft

commonly used does not permit a firing order of 1–2–3–4, but gives firing orders in which numbers one and four must fire alternately. The succession in which power strokes occur is called the firing order.

In the four-cylinder engine numbers one and four pistons are always moving in the opposite direction from numbers two and three. If equal in weight they will balance each other and an engine of this type is said to have good mechanical balance.

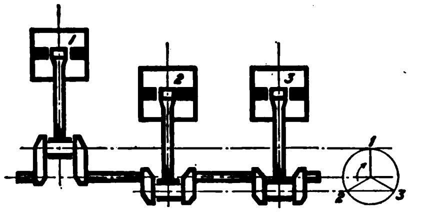
As number one piston is moving outward on power, number four must move outward on suction; number two piston can be moving inward on exhaust or compression and number three will be moving inward on compression or exhaust. Table one shows the power balance with number two piston on exhaust and number three on compression. Table two shows the power balance resulting from number two piston moving inward on compression and number three on exhaust. With either arrangement the power impulses are evenly distributed, that is, they are 180 degrees apart.

Each arrangement gives a different firing order. With the arrangement shown in table one the firing order is 1–3–4–2. With the arrangement shown in table two the firing order is 1–2–4–3. Following are the firing orders of four-cylinder engines in several motor vehicles. It will be noted that the firing order 1–3–4–2 is the most common.

Four-Wheel Artillery Tractor	1–3–4–2
F. W. D.	1–3–4–2
Nash	1–3–4–2
White	1–3–4–2
Dodge	1–3–4–2
Standardized "B"	1–3–4–2
Holt	1–2–4–3
Packard	1–2–4–3
Ford	1–2–4–3

Three-cylinder engines are built with 120 degree crank shafts, that is the crank arms are $\frac{1}{3}$ of a revolution apart instead of $\frac{1}{2}$ revolution as in the 180 degree crank shafts. With this arrangement as shown in Fig. 19, number one piston moves outward on power, number two piston moves inward finishing its exhaust stroke and starts outward on suction, number three piston moves outward finishing its suction stroke and starts inward on compression. As number one piston moves inward on exhaust, number two piston finishes its suction stroke and starts inward on compression, number three piston finishes its compression stroke and moves outward on power. As

number one piston moves outward on suction, number two piston finishes its compression stroke and starts outward on power, number three piston finishes its power stroke and moves inward on exhaust As number one piston moves inward on compression, number two piston finishes its power stroke and starts inward on exhaust, num-



CYLINDER	1	2	3
1ST REVOLUTION	P	E	S
	P	E	C
	P	S	C
	E	S	C
	E	S	P
	E	C	P
2ND REVOLUTION	S	C	P
	S	C	E
	S	P	E
	C	P	E
	C	P	S
	C	E	S

Fig. 19 — Three-cylinder power balance chart

ber three piston finishes the exhaust stroke and starts outward on suction. From the foregoing it can readily be seen that the power impulses will occur every 240-degree movement of the crank shaft. An engine of this type has power balance.

Six-cylinder engines have crank shafts of a similar construction to the three-cylinder; having numbers one and six, two and five, and three and four pistons operating together. With this construction there will be six power impulses during two revolutions which gives very good engine balance.

In Fig. 20 it will be seen that as numbers one and six pistons are starting outward, numbers two and five are completing their outward strokes, and numbers three and four are on their inward strokes. With this arrangement it is possible to obtain four different combinations as shown in tables one, two, three, and four. It is also possible to have numbers three and four pistons finishing their outward strokes as numbers one and six start outward and two and five complete their inward strokes. Combinations as shown in tables five, six, seven and eight will result. With any of these combinations it can be readily seen that the power impulses are evenly distributed and are 120 degrees apart, the only difference being the order in which the cylinders fire.

Table 1. — Firing Order 1–3–5–6–4–2
Table 2. — Firing Order 1–4–5–6–3–2
Table 3. — Firing Order 1–3–2–6–4–5
Table 4. — Firing Order 1–4–2–6–3–5
Table 5. — Firing Order 1–2–4–6–5–3
Table 6. — Firing Order 1–5–4–6–2–3
Table 7. — Firing Order 1–2–3–6–5–4
Table 8. — Firing Order 1–5–3–6–2–4

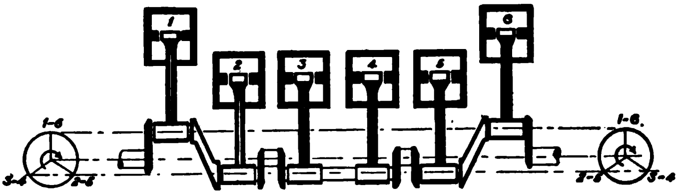


TABLE	I						II						III						IV					
CYLINDER	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6
1ST REVOLUTION	P	P	C	E	S	S	P	P	E	C	S	S	P	S	C	E	P	S	P	S	E	C	P	S
	P	E	C	E	C	S	P	E	E	C	C	S	P	C	C	E	E	S	P	C	E	C	E	S
	P	E	P	S	C	S	P	E	S	P	C	S	P	C	P	S	E	S	P	C	S	P	E	S
	E	E	P	S	C	C	E	E	S	P	C	C	E	C	P	S	E	C	E	C	S	P	E	C
	E	S	P	S	P	C	E	S	S	P	P	C	E	P	P	S	S	C	E	P	S	P	S	C
	E	S	E	C	P	C	E	S	C	E	P	C	E	P	E	C	S	C	E	P	C	E	S	C
2ND REVOLUTION	S	S	E	C	P	P	S	S	C	E	P	P	S	P	E	C	S	P	S	P	C	E	S	P
	S	C	E	C	E	P	S	C	C	E	E	P	S	E	E	C	C	P	S	E	C	E	C	P
	S	C	S	P	E	P	S	C	P	S	E	P	S	E	S	P	C	P	S	E	P	S	C	P
	C	C	S	P	E	E	C	C	P	S	E	E	C	E	S	P	C	E	C	E	P	S	C	E
	C	P	S	P	S	E	C	P	P	S	S	E	C	S	S	P	P	E	C	S	P	S	P	E
	C	P	C	E	S	E	C	P	E	C	S	E	C	S	C	E	P	E	C	S	E	C	P	E

TABLE	V						VI						VII						VIII					
CYLINDER	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6
1ST REVOLUTION	P	C	P	S	E	S	P	E	P	S	C	S	P	C	S	P	E	S	P	E	S	P	C	S
	P	C	E	C	E	S	P	E	E	C	C	S	P	C	C	E	E	S	P	E	C	E	C	S
	P	P	E	C	S	S	P	S	E	C	P	S	P	P	C	E	S	S	P	S	C	E	P	S
	E	P	E	C	S	C	E	S	E	C	P	C	E	P	C	E	S	C	E	S	C	E	P	C
	E	P	S	P	S	C	E	S	S	P	P	C	E	P	P	S	S	C	E	S	P	S	P	C
	E	E	S	P	C	C	E	C	S	P	E	C	E	E	P	S	C	C	E	C	P	S	E	C
2ND REVOLUTION	S	E	S	P	C	P	S	C	S	P	E	P	S	E	P	S	C	P	S	C	P	S	E	P
	S	E	C	E	C	P	S	C	C	E	E	P	S	E	E	C	C	P	S	C	E	C	E	P
	S	S	C	E	P	P	S	P	C	E	S	P	S	S	E	C	P	P	S	P	E	C	S	P
	C	S	C	E	P	E	C	P	C	E	S	E	C	S	E	C	P	E	C	P	E	C	S	E
	C	S	P	S	P	E	C	P	P	S	S	E	C	S	S	P	P	E	C	P	S	P	S	E
	C	C	P	S	E	E	C	E	P	S	C	E	C	C	S	P	E	E	C	E	S	P	C	E

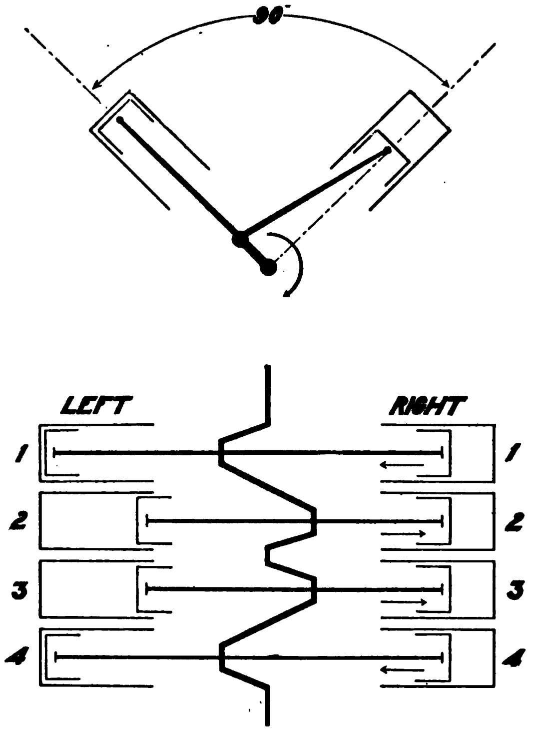
Fig. 20 — Six-cylinder power balance charts

Although there are eight possible firing orders there are only four which are commonly used. The following are seldom used: 1–2–3–6–5–4, 1–5–4–6–2–3, 1–3–2–6–4–5, and 1–4–5–6–3–2. With any of these firing orders the three cylinders at one end of the crank shaft fire and then the three at the other end fire, setting up vibration due to the concentration of the power impulses. For this reason, six-cylinder engines are commonly built to fire so that the impulses are evenly distributed along the crank shaft.

Eight-cylinder engines for motor vehicles are usually constructed by arranging two four-cylinder engines to operate from a single four-throw 180 degree crank shaft of the same form used in the four-cylinder engine. The cylinders are set so that their center lines form an angle of 90 degrees and for this reason such engines are called "V–Type." The connecting rods of the cylinders on the right operate on the same crank pins as the corresponding connecting rods for the cylinders on the left. It must be borne in mind that these connecting rods operate independently of each other. Therefore the operations of the cylinders on the right are always 90 degrees different from the cylinders on the left, that is, when number one piston on the right is at top dead center, number one piston on the left will have completed one half its stroke (Fig. 21).

The table showing the power balance is based on the arrangement used in the Cadillac "8." As number one piston on the left is moving outward on power, number four piston on the left is moving outward on suction, number two piston on the left moving inward on exhaust, and number three piston on the left moving inward on compression. The movements on the right-hand side will be half completed, therefore, number one piston will be completing suction, number four piston will be completing power, number two piston will be completing compression, and number three piston will be completing exhaust. Working out the operations for each 90-degree movement of the crank shaft will give the results shown in the table. There is a power impulse for every 90-degree movement of the crank shaft, giving a firing order as follows: 1L–2R–3L–1R–4L–3R–2L–4R. The power impulses are regular and very frequent in an engine of this type insuring very good engine balance.

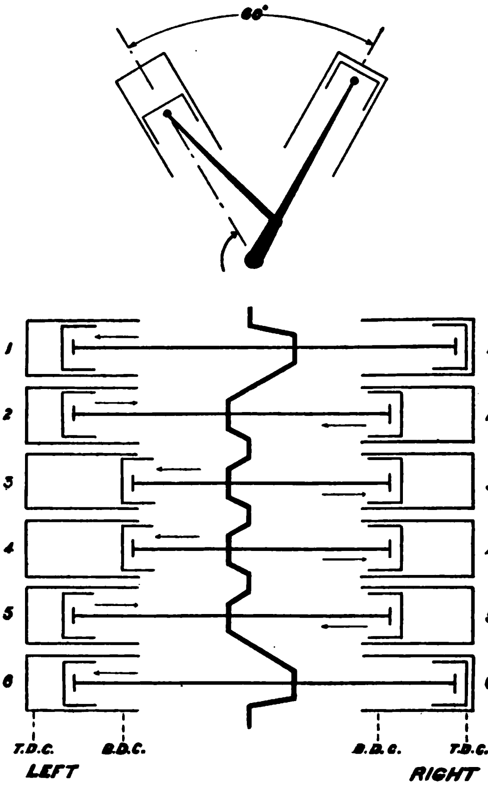
The twelve-cylinder engine is also a "V–Type" and consists of two sets of six cylinders arranged similarly to the "V–Type" eight-cylinder engine except that the angle between the center lines of the cylinders is 60 degrees. A regular six-throw 120-degree crank shaft is used, two connecting rods being attached to each crank pin



	LEFT				RIGHT			
CYLINDER	1	2	3	4	1	2	3	4
1ST REVOLUTION	P	E	C	S	S	C	E	P
	P	E	C	S	C	P	S	E
	E	S	P	C	C	P	S	E
	E	S	P	C	P	E	C	S
2ND REVOLUTION	S	C	E	P	P	E	C	S
	S	C	E	P	E	S	P	C
	C	P	S	E	E	S	P	C
	C	P	S	E	S	C	E	P

Fig. 21 — Eight-cylinder power balance chart

(Fig. 22). The table shown is based on the arrangement used in the Packard Twin Six; starting with number one piston on the right at top dead center and moving the engine 60 degrees or one third of a complete stroke and showing the changes that take place. This table shows that a fresh power impulse is given the crank shaft for each 60-degree movement which gives unusually good engine balance. The firing order of this engine is 1R–6L–4R–3L–2R–5L–6R–1L–3R–4L–5R–2L.



There are many possible firing orders for eight and twelve-cylinder "V-Type" engines other than the ones given. The firing order depends upon the arrangement of the cams on the cam shaft and any combination will give equally good power balance.

The one-cylinder engine having but one power impulse for two revolutions of the crank shaft does not run smoothly or quietly due to the size of the cylinder and time between impulses. This fact led to the adoption of the two-, four-, and six-cylinder engines and quite recently, the eight- and twelve-cylinder engines have come into use. As the number of cylinders is increased, the power impulses increase in fre-

	RIGHT						LEFT					
CYLINDER	1	2	3	4	5	6	1	2	3	4	5	6
1ST REVOLUTION	P	S	E	C	P	S	E	P	C	E	S	C
	P	C	E	C	E	S	S	P	C	E	S	P
	P	C	S	P	E	S	S	E	C	E	C	P
	E	C	S	P	E	C	S	E	P	S	C	P
	E	P	S	P	S	C	C	E	P	S	C	E
	E	P	C	E	S	C	C	S	P	S	P	E
2ND REVOLUTION	S	P	C	E	S	P	C	S	E	C	P	E
	S	E	C	E	C	P	P	S	E	C	P	S
	S	E	P	S	C	P	P	C	E	C	E	S
	C	E	P	S	C	E	P	C	S	P	E	S
	C	S	P	S	P	E	E	C	S	P	E	C
	C	S	E	C	P	E	E	P	S	P	S	C

Fig. 22 — Twelve-cylinder power balance chart

quency. The average power is greater, and above four cylinders there is no period during which some cylinder is not delivering power. This means that in a six-, eight-, or twelve-cylinder engine there is no time at which the flywheel must supply all the power required to maintain the engine speed.

The multi-cylinder engine, therefore, furnishes a practically continuous flow of power with little vibration. The increase in the number of cylinders permits reduction in the size of each cylinder and this combined with the steady operation of the engine makes the modern automobile engine a very quiet, smooth-running, power unit.

As shown in valve timing, the average length of the power impulse is 145 degrees and from Fig. 23 it can be seen that as the number of cylinders is increased the power impulses extend over a greater range. For engines having more than four cylinders the power impulses are continuous and overlap, the length of overlap increasing with the number of cylinders.

Engines of more than four cylinders will have several possible firing orders. The exact firing order of the engine will depend upon the arrangement of the cams on the cam shaft. Therefore, the firing order can be determined by checking a certain operation of the valves such as the opening of the inlet or the opening of the exhaust, or by checking the compression. The firing order thus obtained will correspond to that of the power balance chart worked out for any particular engine. For example, take the power balance chart of a four-cylinder engine, as shown in Fig 18. If the order in which the suction strokes, the exhaust strokes, or the compression strokes occur is taken the same firing order results.

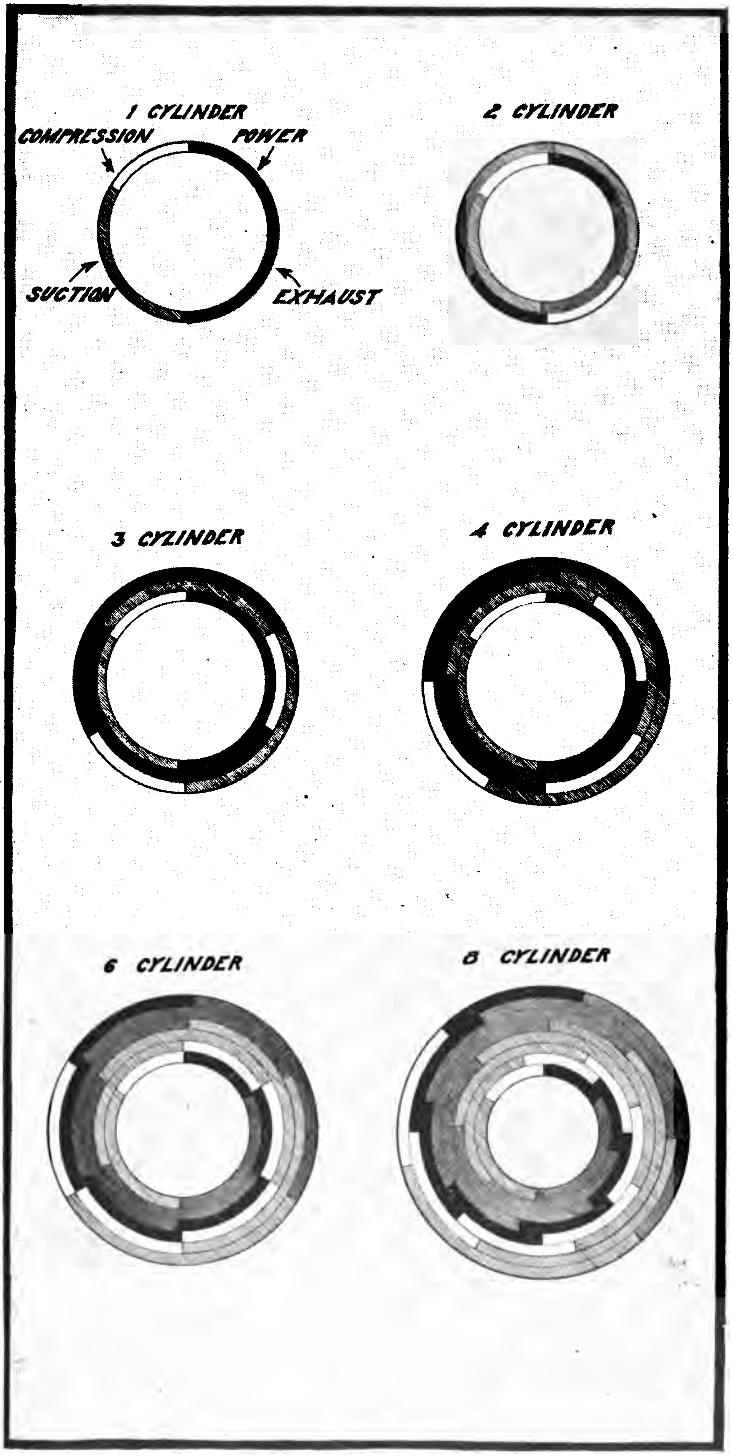


Fig. 23 — Power overlap charts

CHAPTER V

COOLING SYSTEMS

As previously shown the internal combustion engine is a machine for transforming heat into mechanical energy. As the heat increases a greater expansion of the gases results and more power is developed. However, there are certain limitations to the degree of heat that can be maintained in the engine and if the temperature were allowed to rise above a certain limit the degree attained would cause mechanical troubles. The intense heat would cause the cylinder to be scored, the valves to warp, and the lubricant to be burned up causing the piston and bearings to bind. It would also cause the incoming charge to become expanded and thereby cause a rarefied mixture and preignition. In addition to these things the spark plugs would crack and the temper would be taken out of the valve springs. From this it can readily be seen that some method of cooling the engine must be adopted.

As shown in the second chapter a considerable amount of heat is lost in cooling but this cannot be materially reduced for the temperature of combustion far exceeds the temperature at which the engine could operate. The duty of the cooling system is to keep the engine from attaining a temperature which would stop its operation and is not to keep the engine cool, for in so doing it would increase the cooling losses and lower the efficiency. It is a misinterpreted idea in many cases that the cooling system is to keep the engine very cool. It has been found in testing engines that they operate best when the water, leaving the water jacket, is over 160° but well under the boiling point. There are three general systems of engine cooling in common use. First, by air which cools the engine by direct radiation. Second, by water which cools the

Fig. 24 — Air cooled cylinder

engine. Third, by the use of water to cool the engine and air to assist in the cooling of the engine and to cool the heated water.

There are certain things which must be taken into consideration when cooling an engine by air. First, the cooling depends upon the amount of surface presented to the air. Therefore, in motor-cycles the effective outer surfaces of the cylinders are increased by the addition of fins or flanges cast on them and presenting a greater surface for cooling as shown in Fig. 24. Second, the cooling depends upon the amount of air passing over the cooling surface. As the amount of air passing over this surface is increased the cooling will be proportionately increased. On motor-cycles where there is no fan to keep the air in circulation it is essential that the motor-cycle be kept in motion as long as the engine is running, otherwise overheating of the engine will result. Third, the cooling depends upon the temperature of the air passing over the cooling surface. This results in the engine being kept cooler in cold weather than in warm weather. The rear cylinder of multi-cylinder engines will not be cooled the same amount as the front cylinder. This is because the air becomes heated after passing the front cylinder, therefore, it cannot have an equal cooling effect on the rear cylinders.

With twin-cylinder motor-cycles difficulty will often be experienced with the rear cylinder due to this unequal cooling. There is more probability of carbon being formed in this cylinder which will lead to ignition troubles and engine troubles in general. In case a miss in one cylinder is noted it is best to look first for the trouble in the rear cylinder.

Because of its simplicity and light weight the air-cooled engine is particularly suitable for motor-cycle engines. The small size of the engine together with its exposed cylinders insures proper cooling and makes this type of cooling ideal for the motor-cycle.

When water is employed in cooling it must circulate through jackets around the combustion chamber and be kept in motion either by heat or forced circulation. In some stationary engines and motor boats the heated water is not reused. In large stationary engines and very small stationary engines a larger amount of water is used and the cooling of same is by direct radiation. In automobile practice the water from the cylinders is passed to the radiator where it is cooled by air being drawn through the radiator by a fan. There are three general systems of water cooling in use: the Thermo Syphon, the Force System, and Thermostatic Controlled.

The Thermo-Syphon Cooling System, shown in Fig. 25, is a typical construction. The water enters the cylinder jacket at *A* and upon becoming heated by the combustion within the engine, rises and enters the pipe *B* and passes to the radiator *C* where it is brought into contact with a large cooling surface *D*. When water is cooled it becomes heavier and therefore sinks to the bottom of the cooling system. As the water is heated in the cylinder jacket and rises to the top it must be replaced by cool water and therefore the water from the lower pipe *A* enters the water jacket.

It can readily be seen that this circulation is proportional to the heat and as the heat increases the circulation becomes faster. This

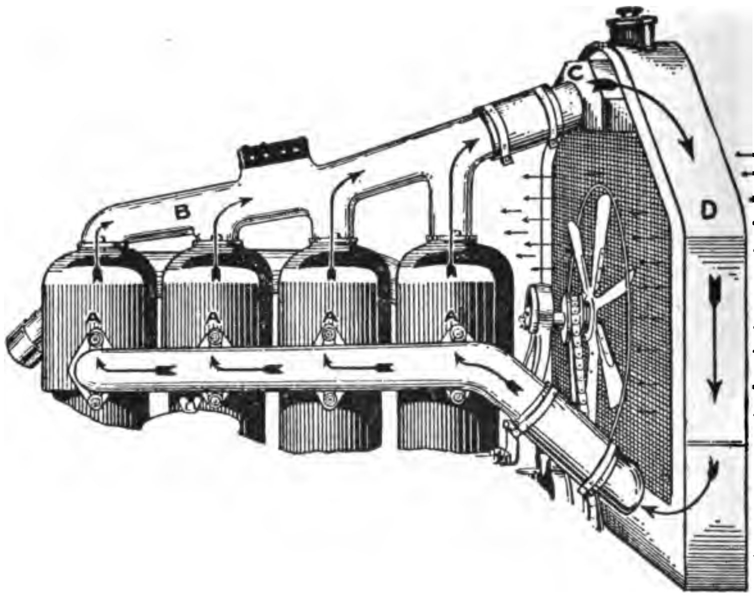


Fig. 25 — Thermo-syphon cooling system

is an ideal condition for keeping the engine at the proper temperature. Since there could be no circulation when the engine is cold the possibility of cold water continuously passing through the water jacket is eliminated, a condition which would keep the engine at a temperature less than should be maintained for proper efficiency. As the circulation depends solely upon the heat it is not positive and a slight amount of foreign matter obstructing the passages would interfere with the circulation. Another objection to the Thermo-Syphon system is that in case enough water evaporates, the water level will fall below the pipe entering the radiator, the circulation will stop, and the engine overheat. To prevent this it is essential

that the radiator be kept completely filled. In extremely cold weather freezing of the lower pipe may occur after the car has been on the road for a short time. This is due to the circulation being very sluggish in cold weather and the last point reached by the water warmed in the cylinders is the lower pipe. As soon as freezing takes place circulation stops and overheating results. The water in the jackets is heated and rises to the top but cannot pass down through the radiator to be cooled. This trouble arises from not running the engine sufficiently to warm up all the water in the cooling system before starting out.

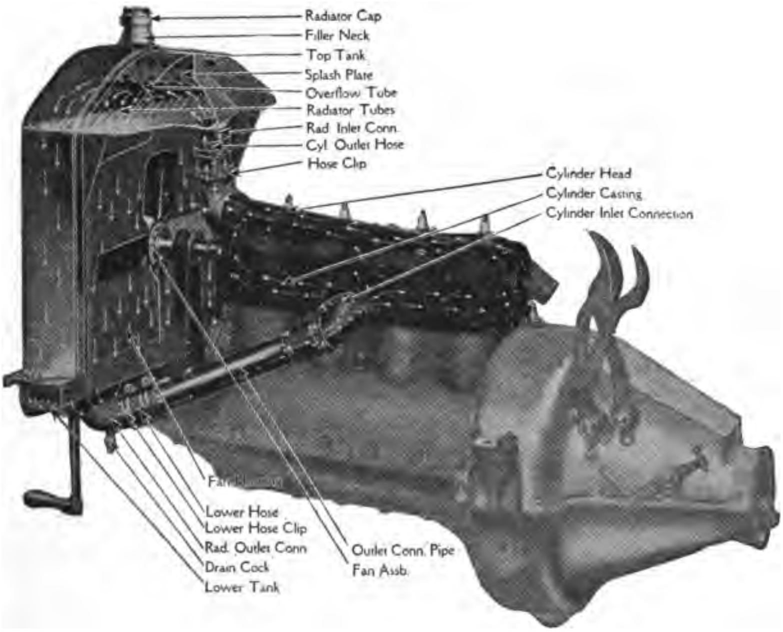


Fig. 26 — Ford cooling system

Figure 26 shows a typical Thermo-Syphon system. The arrows indicate the course of the water through the water passages. This is one of the few American motor cars that retains the Thermo-Syphon cooling system.

The Force Cooling System shown in Fig. 27 is a typical construction. In this system water leaves the cylinder jackets through the pipe from the cylinder head and enters the radiator through the radiator inlet pipe. The water passes through the radiator where it is cooled by the air drawn through the radiator. From the radiator the water passes through the radiator outlet pipe and through the pump to the cylinder jackets.

While the engine is in operation the pump, being geared to it, causes the water to circulate so that slight obstructions will not clog up the system. In case the radiator is not completely filled the pump will still circulate the water causing it to overflow from the radiator inlet pipe. The only part of the system is which there will be no water will be the upper section of the radiator. The level in the radiator will depend upon the quantity of water in the system. If there is too little water the level will be so low that the efficiency of the radiator in cooling the water will be reduced to such an extent

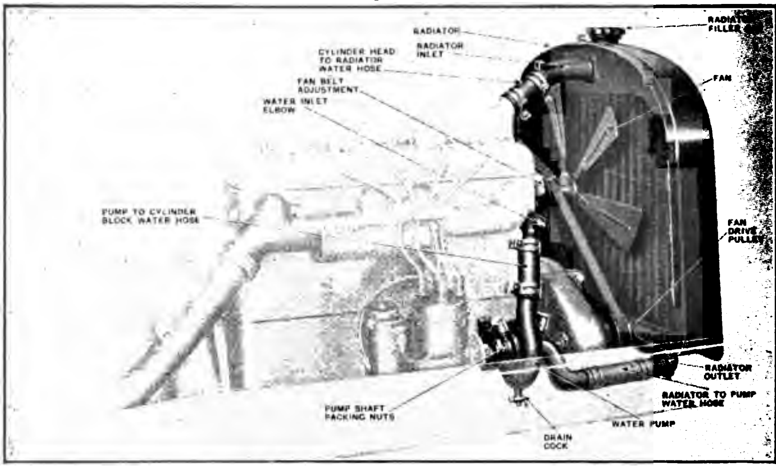


Fig. 27 — Dodge cooling system

that overheating will often result. Since the water is always in circulation when the engine is running there is little possibility of freezing.

As the pump is positively geared to the engine the circulation will be proportional to its speed and for a given speed the amount of cooling will vary according to the temperature of the air. On a cold day as much water is passed through the water jackets as on a warm day, but the temperature of the water is considerably lower and the engine is kept too cool resulting in considerable loss of efficiency. This is particularly noticeable when starting an engine in cold weather for it causes misfiring due to the cold water being circulated through the water jackets. To prevent excessive cooling of the engine, which reduces its efficiency, the fan may be disconnected thereby reducing the cooling power of the radiator. A more satisfactory method is to cover part of the radiator's cooling surface. The best results are obtained when an adjustable device or shutter is used.

Natural circulation is of practically no assistance in the Force Cooling System; it depends entirely upon the pump for circulation. This permits the use of smaller water jackets and piping and as it is the practice to construct the engine as light as possible, these are made as small as practicable. In case any difficulties arise which stop the operation of the pump, natural circulation cannot be depended upon sufficiently to cool the engine as it does in the Thermo-Syphon System, where large water jackets and pipes are used.

The Thermostatic Controlled Cooling System. — A Thermostatic device is introduced in this system in order to overcome the difficulties which arise in the Forced Cooling System when cooled water is circulated through the water jackets. The temperature of the liquid circulated by the pump is under Thermostatic control. The purpose of this is to permit water circulating through the water jackets of the cylinders and carburetor intake manifold to warm up to the temperature at which the engine operates best, very soon after the engine is started and to prevent the temperature dropping below this point while the engine is running. To explain the operation of the Thermostatic Controlled Cooling System, those used on the Cadillac and Packard will be described.

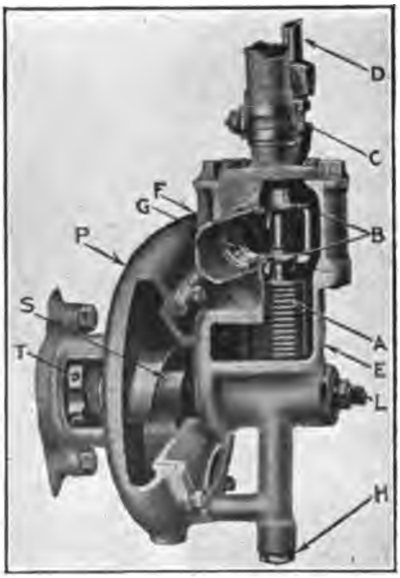


Fig. 28 — Thermostat regulator on Cadillac

On the Cadillac the circulation through each cylinder block is independent of that through the other, two separate pumps being provided. Two centrifugal pumps are located at the front end of the crank case, on each side, and are driven from the crank shaft through helical gears. A housing containing a Sylphon Thermostat and a valve controlled by the Thermostat are located on the cover of each water pump. The Thermostat *A* (Fig. 28) is accordion shaped. It contains a liquid which is converted into gas when heated. The resulting pressure elongates the Thermostat, forcing the valve B from its seat. A drop in temperature changes the gas to a liquid, reducing the pressure in the Thermostat, bringing the valve *B* back to its seat.

When the temperature of the water in the water jackets on the cylinders and intake manifold is below a predetermined point the valve *B* is held tightly closed by the Thermostat which prevents water being drawn from the radiator. When the temperature of the water tends to rise above the predetermined point the valve *B* is forced open by the Thermostat, permitting the water pump *P* to draw water from the radiator. Provision is made for forcing the valves operated by the Thermostat from their seats. This is necessary to drain the radiator.

When the engine is first started and is cold the valves operated by the Thermostats are held tightly on their seats. This prevents the water pumps from drawing water from the radiator. Under

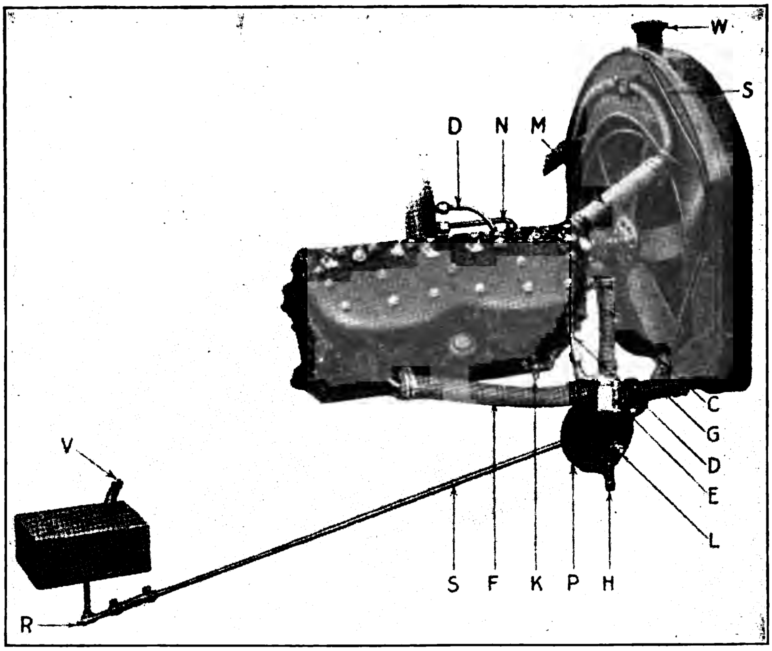


Fig. 29 — Cadillac cooling system

these conditions the water is circulated as follows: From the water pump *P* (Figs. 28 and 29) through the hose *F* to the water jackets on the cylinders, from the water jackets on the cylinders some of the water returns to the pump *P* through the hose *C* and the Thermostat housing *E* and the remainder is carried by a small pipe *N* to the water jacket around the intake manifold and from the intake manifold to the pump *P* through the pipe *D* and the Thermostat housing *E*.

After the engine has become warm and the valves between the pumps and radiator have been forced from their seats by the Thermostats the circulation is as follows: Water is drawn from the radiator through the hose *G* and forced to the water jackets on the cylinders through the hose *F*, from the water jackets the water returns to the radiator through the hose *M* connecting the cylinder block and radiator. Water is still forced to the water jackets on the intake manifold through the small pipe *N* and from the intake manifold to the pump *P* through the pipe *D* and the Thermostat housing *E*. Some of the water still flows back to the pump through the hose *C* and the Thermostat housing *E*.

As the temperature of the water returning to the pump through the pipe *D*, hose *C*, and Thermostat housing *E* rises or falls, the Thermostat expands or contracts, opening or closing the valve, thereby admitting a larger or smaller amount of the cooled water from the radiator. A condenser, the purpose of which is to prevent the loss of the cooling medium by evaporation particularly when an alcohol solution is used, is attached to the right-hand side of the frame just beneath the front floor boards. A pipe *S* (Fig. 29) connected to the overflow tube of the radiator leads to the condenser.

The condenser acts in this manner. The vapor rising from the heated liquid in the radiator passes through the overflow tube to the condenser. As it passes into the liquid in the condenser the vapor is condensed. When the engine has stopped the cooling of the radiator and its contents results in the contraction and condensation of the vapor left in the upper part of the radiator. The partial vacuum thus caused allows the atmospheric pressure in the condenser to force condensed vapor back into the radiator. The proper operation of the condenser requires an air-tight joint at the radiator filler cap. To make it possible to screw down and tighten the cap without injury to the rubber gasket, two metal washers are interposed between the head of the cap and the gasket. It is important that nothing be installed on the radiator filler cap which might cause a leak at the cap or which might make necessary the elimination of the steel washers or the cutting of a hole through the rubber gasket.

In the Thermostatic Controlled Cooling System as used on the Packard (Fig. 30) there are two paths through which the water may circulate. The water is forced by the pump through the cylinder water inlet manifold, thence through the water jackets, and out through the pipe at the top of the cylinder block. From here it may pass either through the bypass manifold directly to the pump or through the radiator returning to the pump by the lower pipe.

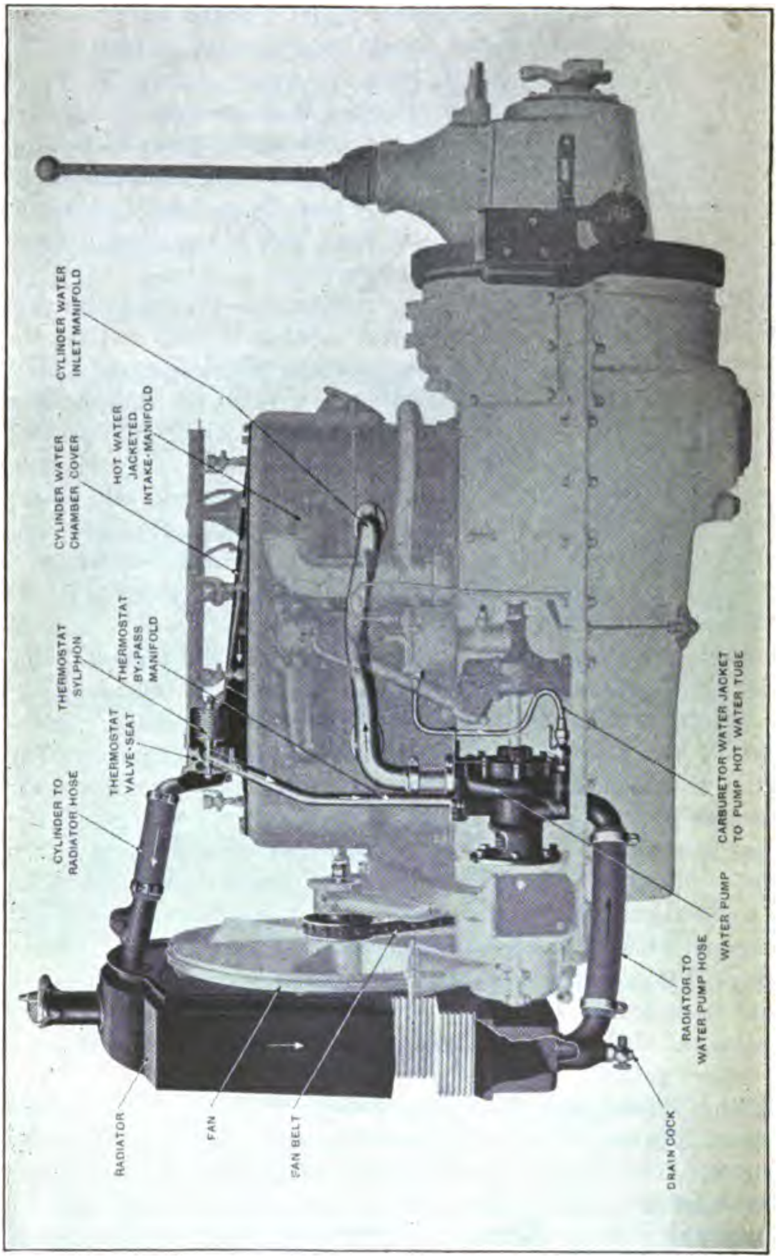


Fig. 30 — Packard cooling system

The path which the water takes is regulated by the Thermostat which operates a valve in the pipe leading to the radiator. The operation of the Thermostat is identical with that on the Cadillac, the only difference being its location.

Fig. 31 — Phantom view of centrifugal pump

The great advantage of a Thermostatic Controlled Cooling System is its efficient operation in cold weather in preventing cold water being circulated through the water jackets and cooling the engine below an efficient running temperature. There is little possibility of the radiator freezing because the length of time required to heat the small quantity of water in the jackets is very short. This results in sending a quantity of heated water almost immediately into the radiator. The Thermostat will gradually permit the heating of the water in the entire system always maintaining the water in the jackets at approximately the same temperature.

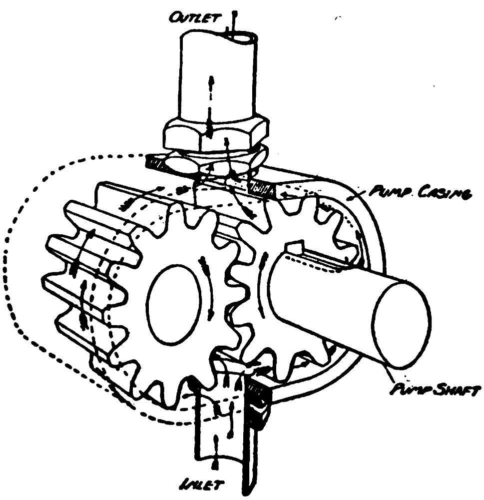


Fig. 32 — Gear pump

Pumps. — There are several constructions of pumps used for water circulation, the most common of these being the centrifugal and gear types.

In the centrifugal type (Fig. 31) the water enters at the center of

the pump and caught by the rotating blades and thrown to the outside by centrifugal force. The casing limits its outward motion, but allows the blades to impel it in circular motion, the pressure against the casing increasing until the outlet pipe is reached. Here the resistance to its outward motion is removed and the stored-up energy forces the water through the discharge pipe to the water jackets.

In the gear pump (Fig. 32) the water takes the path indicated by the arrows. The gear teeth pick up the water and carry it around in the spaces between the teeth, the pump casing making a tight joint. The teeth of the two gears meshing at the center prevent any water being carried down between them, hence a steady stream of water will be forced out of the discharge pipe.

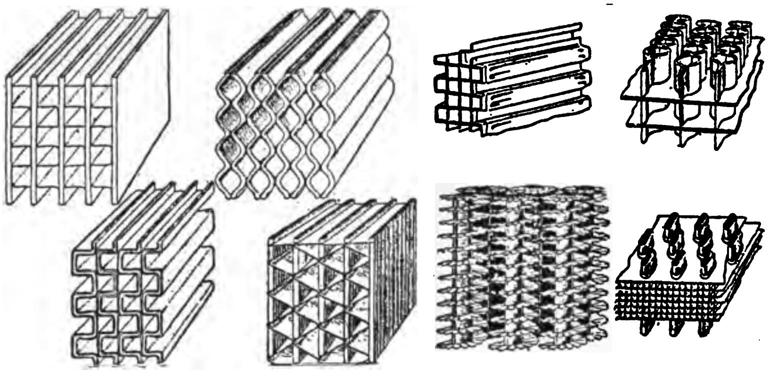


Fig. 33 — Tubular radiator sections

Radiators. — The purpose of a radiator is to present a large amount of cooling surface to the air. In order to accomplish this there are many constructions varying in design in accordance with the manufacturer's ideas. All radiators may be classed as either tubular or cellular. The so-called honeycomb radiator may be either tubular or cellular (though generally the latter) and gets its name from its appearance.

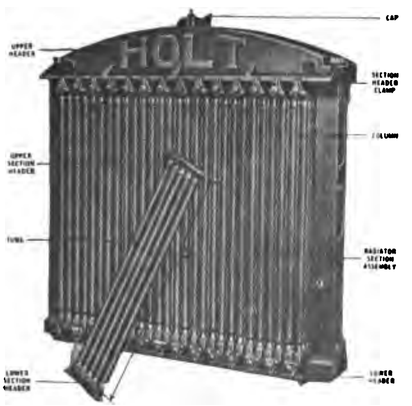


Fig. 34 — Tubular radiator

The tubular radiator is one in which the upper and lower tanks are connected by a series of tubes through which the water must pass. The tubes may be arranged vertically or in a zig-zag fashion which materially increases the cooling surface.

In Fig. 33 typical tubular constructions are shown, that in the lower left-hand corner being a honeycomb type.

In Fig. 34 a straight vertical tube type of radiator is shown and is typical of the construction used for trucks. To increase the radiating surface fins are employed on the tubes

The cellular radiator (Fig. 35) is composed of a large number of individual air cells which are surrounded by water and the course of

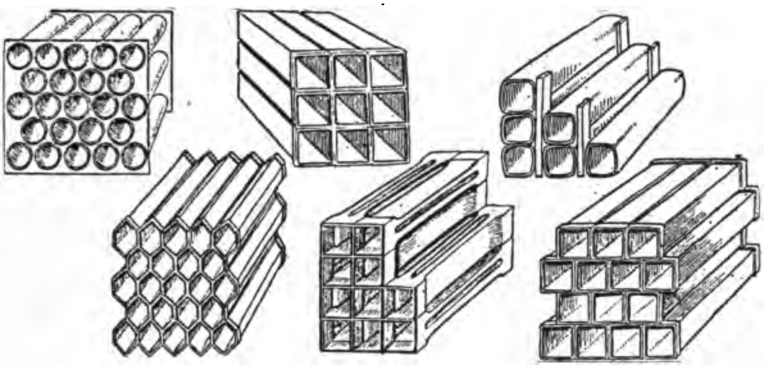


Fig. 35 — Cellular radiator sections

the water through the radiator is not confined to any definite vertical or angular course. Because of its appearance the cellular type is usually known as a " honeycomb " radiator.

Since the water passes through all of the tubes of a tubular radiator, if one tube becomes clogged the cooling effect of the entire tube is lost. In the cellular construction the clogging of any passage results in a loss of but a very small part of the total cooling surface as compared to the loss of a whole tube in the tubular type. For this reason the cellular or commonly called " honeycomb " radiator is more efficient but is more expensive to construct.

Fans. — In order to cool the water sufficiently a fan driven by a belt or chain from the engine is placed back of the radiator so that in its operation it will draw air through the radiator. In many constructions of radiators the mere motion of the car could not force sufficient air through the radiator but, by placing a fan behind it, sufficient air will be drawn through for cooling purposes. It is a misinterpreted idea that a fan is used to cool the engine, its function being solely to assist in cooling the water in the radiator. In some constructions it may assist slightly in cooling the engine.

The fan bracket is so constructed that the tension on the belt is adjustable. At all times the belt should be under sufficient tension to prevent slippage. Fans require but little power and usually run at a speed two or three times as great as that of the crank shaft

and are mounted on ball-bearings to reduce friction as much as possible.

Anti-Freezing Mixtures. — In order to prevent the water in the cooling system from freezing in extremely cold weather when the engine is not in operation there is provided at the bottom of the radiator, at the lowest points in the water jackets, and at the pump, drain cocks through which the water can be removed. Water in freezing expands and if confined in the cooling system would cause the water jackets, pipes, or radiator to break. As an assurance in freezing weather that the cooling system of a car has been drained and as an indication that it must be filled before operating the car a card marked **DRAINED** in black letters about three inches high should be conspicuously displayed. This is usually done by suspending the card across the radiator from the filler cap. As it is often found undesirable to remove the water from the cooling system, fluids with very low freezing points are often employed. These are called anti-freezing mixtures. The ideal requirements for an anti-freezing mixture are as follows:

1. It should cause no harmful effect to any part of the cooling system with which it comes in contact.
2. It should be easily dissolved or combined with water.
3. It should be reasonably cheap.
4. It should not waste by vaporization, that is, its boiling point should be as high as that of water.
5. It should not deposit any foreign matter in the jackets or pipes.

The materials which are most commonly used are alcohol, mixtures of alcohol and glycerine, kerosene oil, and calcium chloride. The most common of these are solutions of alcohol and water in the following proportions:

Water	Alcohol	Spec. Grav.	Freezing Point
80%	20%	.975	14°
70%	30%	.964	– 1°
60%	40%	.954	–20°

The above table is based on the use of denatured alcohol but if wood alcohol is used, slightly lower temperatures can be reached with the same proportions of alcohol and water. In these solutions, the alcohol being more volatile than water, will evaporate making it necessary continually to add more alcohol. The use of this solution is very unsatisfactory because the only method of being positive that the alcohol is present is by measuring the specific gravity of the solution.

There are certain solutions of glycerine, alcohol, and water which are more stable because the glycerine holds the alcohol in solution. The following table shows the percentage of each and the freezing points of the solutions:

Alcohol	Glycerine	Water	Freezing Point
12%	12%	76%	10°
15%	15%	70%	– 5°
17%	17%	66%	–15°

These solutions are very satisfactory as they are dependable, but it often happens that the glycerine will gum up the radiator and stop the circulation of the water through some section thus reducing the cooling

Calcium chloride or alkali solutions are often recommended, their freezing points being very low. The great objection to the use of these is that they form a scale in the water jackets and radiator which in time interferes with the circulation. When calcium chloride is used it must be chemically pure as the commercial chloride of lime sets up electrolytic action. The following solutions are used:

Calcium Chloride	Water	Spec. Grav.	Freezing Point
20%	80%	1.119	0°
22%	78%	1.200	– 9°
24%	76%	1.219	–18°

Kerosene has the advantage of a high boiling point so that it does not evaporate readily but it has the disadvantage of not making a good mixture with water and will not absorb heat as rapidly. Kerosene should not be used where there is any rubber in the system for it attacks the rubber hose and gaskets and causes them to deteriorate rapidly.

Whenever an anti-freezing mixture is used it is essential that it be removed from the cooling system as soon as the weather moderates. If this is not done the engine will overheat.

If the water in the cooling system should freeze through neglect of ordinary precaution do no attempt to thaw it by starting the engine, but thaw by putting the car in a warm place or by draining the system and then adding hot water. It has been stated that solutions of calcium chloride deposit a scale in the water jackets and radiator and therefore should not be used. There are many places in which the drinking water contains a considerable amount of lime which will cause the same result. To prevent scale it is always best to fill the cooling system with rain water.

CHAPTER VI

FUEL FEED SYSTEMS

Provision must be made on motor-propelled vehicles for storing gasoline and supplying it to the carburetor. There are three systems in common use for supplying liquid fuel to the carburetor from the storage tank, the Gravity System, the Force Feed System, and the Vacuum System.

Gravity System. — In the gravity fuel feed system the storage tank must be placed above the carburetor so that the gasoline will flow from it to the carburetor by gravity. A typical system of this kind is shown in Fig. 36. It is very simple and has but a few parts. The storage tank has a filler cap in the top with an air vent through it and a gasoline outlet at the bottom which leads to a sediment well

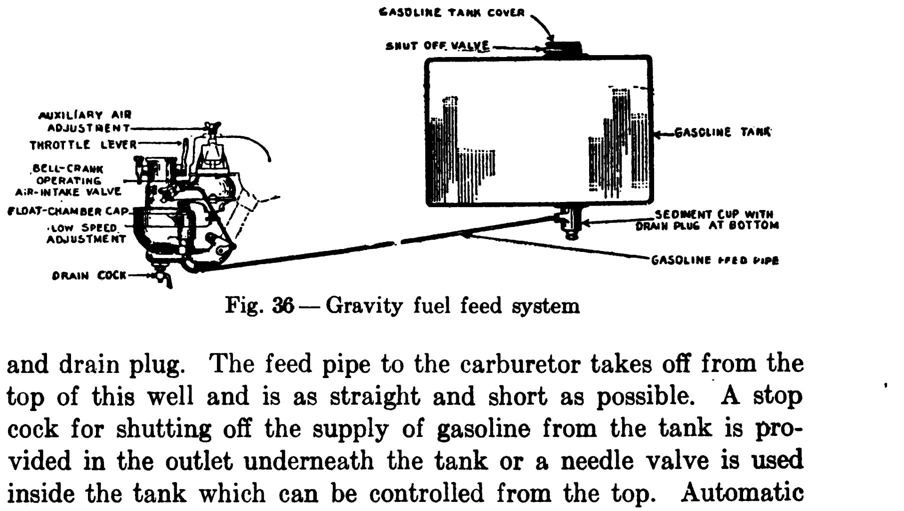


Fig. 36 — Gravity fuel feed system

and drain plug. The feed pipe to the carburetor takes off from the top of this well and is as straight and short as possible. A stop cock for shutting off the supply of gasoline from the tank is provided in the outlet underneath the tank or a needle valve is used inside the tank which can be controlled from the top. Automatic gauges are sometimes provided on the storage tank to show the amount of fuel in the tank.

Because of the simplicity of construction they are not apt to get out of order. On the other hand they have several drawbacks. The pressure varies with the relative height of tank and carburetor and since this is usually not very great the resulting pressure will be low. When ascending or descending grades the relative height of the tank and carburetor will change, which correspondingly varies

the pressure. Since the tank must be above the carburetor for this system to be operative its location is very limited and it generally has to be placed at some point not readily accessible. This fact also makes it hard to shut off the supply of gasoline and in case fire occurs at the carburetor the result may be serious, if the supply of gasoline is not immediately shut off.

Pressure System. — When the pressure fuel feed system is employed the storage tank may be placed at the most convenient and accessible point on the machine usually at the extreme rear of the chassis. When installed in this manner it is necessary to force gasoline out of the tank by air pressure since the gasoline tank is lower than the carburetor. Pressure is maintained by a small air pump automatically controlled and driven by the engine. An

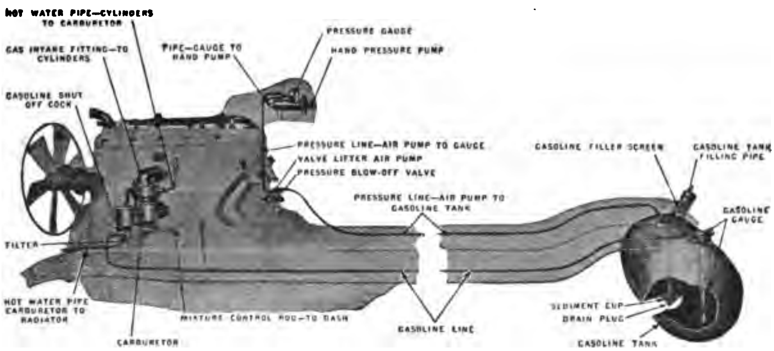


Fig. 37 — Pressure fuel feed system

auxiliary hand pump gives enough initial pressure to force gasoline to the carburetor for starting. A safety valve in the pressure system prevents the pressure from rising beyond a safe limit. The tank must be air-tight and the filler cap screwed tight with a wrench to hold the pressure. A gasoline gauge is provided to show how much gasoline the tank contains. Two pipes run from the tank, one being the pressure line and the other the gasoline line (Fig. 37). The gasoline line runs from the lowest point in the tank directly to the carburetor. The pressure line is connected to both the engine-driven pump and the hand pump. The hand pump is shut off by means of a valve at its lower end when not in use. A pressure gauge may be attached to this line near the hand pump to show the pressure in the system at all times. Some systems have the pressure gauge attached to the gasoline line.

Since a constant pressure is maintained in the tank at all times the gasoline is fed uniformly to the carburetor and its flow is independent of the relative position of tank and carburetor. In addi-

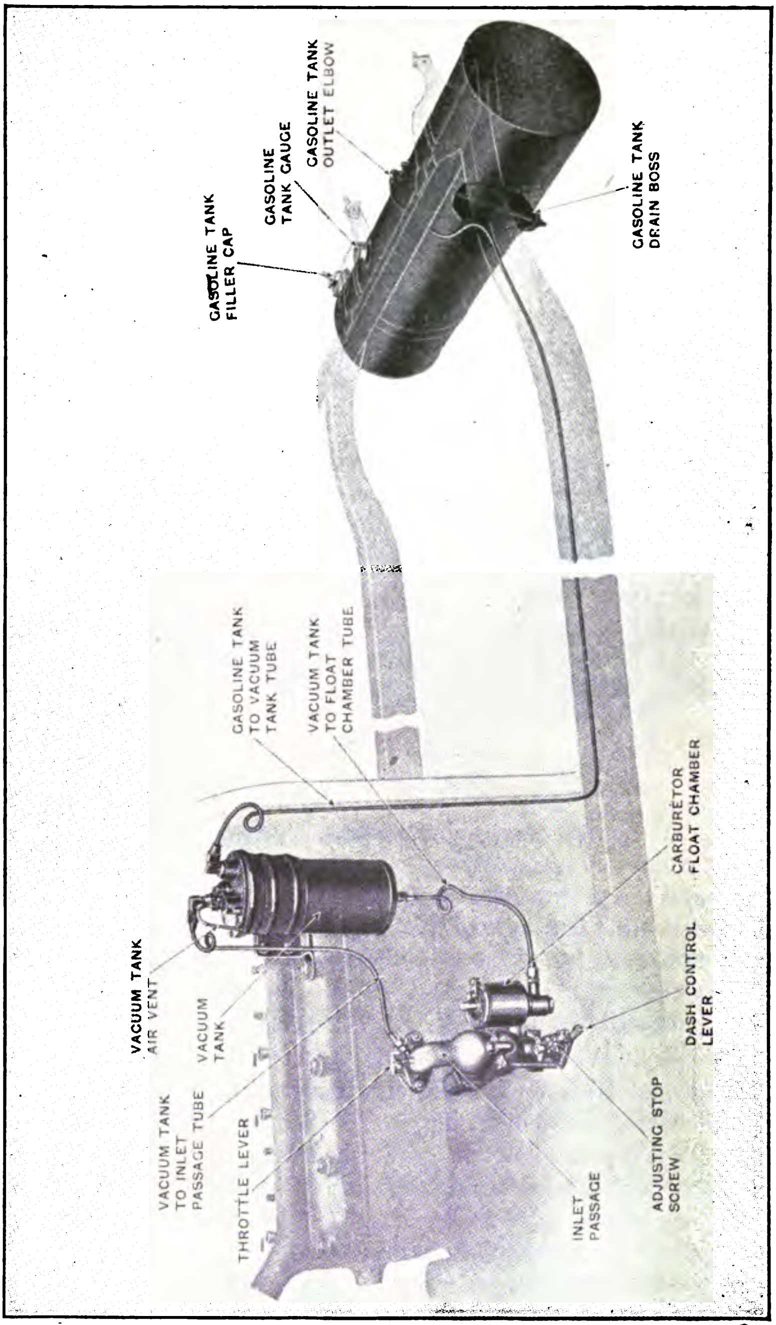


Fig. 38 — Vacuum fuel feed system

tion to this the location of the tank is not limited, permitting it to be placed in an accessible position where gasoline may be put in with the greatest facility. Should fire occur at the carburetor the supply of gasoline can immediately be shut off at the dash by turning the cock at the hand pump so that the pressure in the system can escape to the air. Trouble may be experienced in this system with leaks in the various pipes, valves, or filler cap and the pumps must be in proper working order for constant operation. In addition the pressure is liable to interfere with the operation of the carburetor float and prevent the needle valve from seating properly. However, the pressure feed system has been so highly perfected that few mechanical difficulties are apt to be experienced.

Vacuum System. — In this system the gasoline is drawn from a supply tank in the rear of the car by suction to a small auxiliary vacuum tank near the engihe from which it flows by gravity to the carburetor. The vacuum tank is installed under the hood and connected by tubing to the intake manifold, gasoline storage tank, and carburetor (Fig. 38). The suction created by the pistons on their outward strokes in the engine causes a suction in the vacuum tank through the connection to the intake manifold. This draws gasoline from the main supply tank into the vacuum tank through the tubing from the gasoline supply tank.

The Stewart Vacuum Gasoline Tank consists of two chambers. The upper is the filling chamber and the lower is the emptying chamber. Between these two chambers is a partition in which is placed a valve. The suction of the pistons on the intake stroke creates a vacuum in the upper chamber and this vacuum closes the valve between the two chambers and also sucks or pumps up the gasoline from the main supply tank into this upper chamber. As the gasoline flows into this upper chamber it raises a float. When the float has risen to a certain point, it operates a valve which shuts off the suction and at the same time opens an air valve. This admission of outside air releases the vacuum causing the valve leading into the lower chamber to open, through which the gasoline immediately commences to flow into the lower or emptying chamber. This lower chamber is always open to the outside air so that nothing can ever prevent the gasoline in it from feeding through its connection to the carburetor in an uninterrupted flow.

Description of Stewart Vacuum Tank

A is the suction valve for opening and closing the connection to the manifold and through which a vacuum is extended from the engine manifold to the gasoline tank.

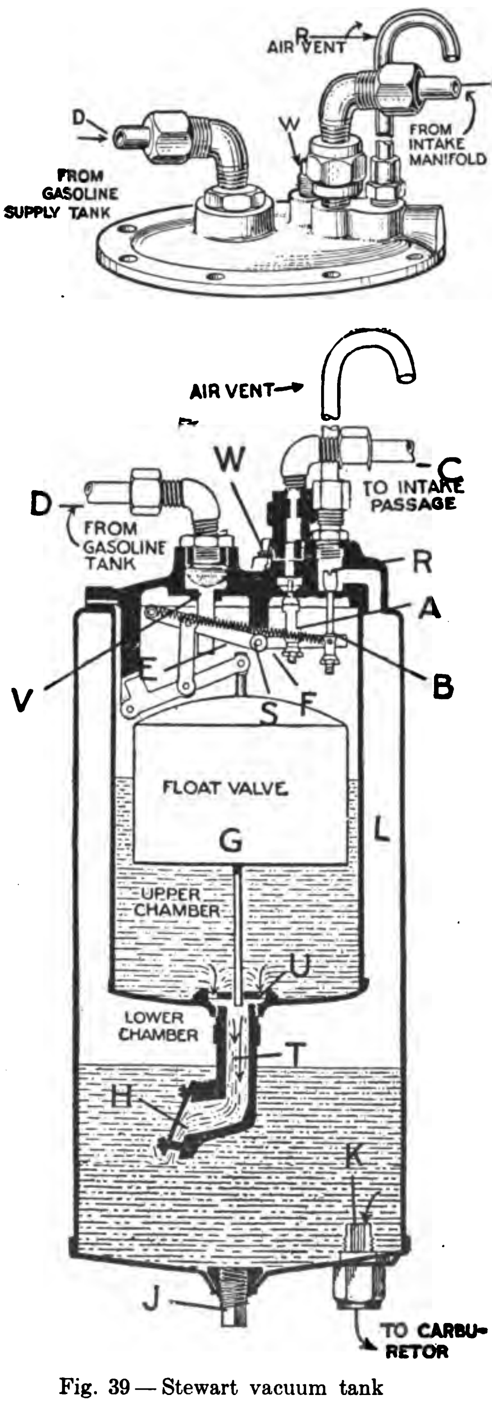


Fig. 39 — Stewart vacuum tank

B is the atmospheric valve and permits or prevents atmospheric pressure in the upper chamber. When the suction valve *A* is open and the suction is drawing gasoline from the main reservoir this atmospheric valve *B* is closed.

C is the pipe connecting the tank to manifold of the engine.

D is the pipe connecting the vacuum tank to main gasoline supply tank.

E is the lever to which the two coil springs *S* are attached. This lever is operated by the movement of the float *G*.

F is a short lever which is operated by the lever *E* and which in turn operates the valves *A* and *B*.

G is the float.

H is the flapper valve in the outlet *T* (Fig. 39). This flapper valve is held closed by the action of the suction whenever the valve *A* is open, but it opens when the float valve has closed the vacuum valve *A* and opened the atmospheric valve *B*.

J is the plug in the bottom of the tank which can be removed for draining or cleaning the tank. This plug can be replaced with a pet cock to be used for drawing off gasoline for priming or cleaning purposes.

K is the line to the carburetor extended on inside of the tank to form a pocket for trapping water and sediment.

L is the channel space between the inner and outer shells and connects with the air vent *R*, thus maintaining an atmospheric pressure in lower chamber at all times. This insures an even flow of gasoline to the carburetor.

R is an air vent over the atmospheric valve. The effect of this is the same as if the whole tank were elevated and is for the purpose of preventing an overflow of gasoline if the storage tank should become higher than the vacuum tank. Through this tube also the lower or reservoir chamber is continually open to atmospheric pressure so that the flow of gasoline from this lower chamber to the carburetor is always an uninterrupted flow. This outlet is located at the bottom of the float reservoir in which is the flapper valve *H*.

The simple durable construction used in the manufacture of the Stewart Vacuum Tank makes it unlikely that it will ever be necessary to make internal repairs. However, some of the following troubles may possibly be experienced. The vent tube may overflow and if it does this regularly the trouble may be:

1. The air hole in main gasoline tank filler cap may be too small or may be stopped up.

2. Vacuum tank may not be placed high enough above the carburetor.

If faulty feed is due to the vacuum system it may result from one of the following causes:

1. Gasoline strainer may be clogged and should be examined first if the tank fails to operate.
2. The float may leak allowing gasoline to be drawn into the manifold which will choke down the engine.
3. Flapper valve may not seat properly.
4. Manifold connection may be loose allowing air to be drawn into it.
5. Tubing may have become stopped up.

This system supplies gasoline at a constant pressure but low enough not to interfere with the action of the carburetor float. This system does not limit the location of the supply tank but eliminates the trouble-giving pumps and valves of the pressure system and permits the final supply of gasoline to the carburetor by gravity.

Care of Gasoline. — Gasoline being a volatile liquid is very dangerous if not properly handled, but is quite safe if the proper precautions are taken. It should never be exposed in a closed room as it will evaporate, mixing with air and forming an explosive gas. Open lights should never be used where gasoline vapor is apt to be encountered. When it is necessary to handle gasoline at night in the open an electric light should be used and under no circumstances should a flame be brought near the gasoline. When an open flame is used at some distance from gasoline, it should always be placed above the gasoline. Gasoline should be stored in an underground tank or an air-tight container in a separate building used especially for that purpose.

In putting out a gasoline fire, water should never be used as the gasoline, being lighter than water, floats on it, resulting in spreading the fire. The only successful method of extinguishing a gasoline fire is to smother it with sand, sawdust, or a blanket or by the use of a chemical fire extinguisher. Each piece of motor equipment should be provided with a small chemical extinguisher for this purpose.

CHAPTER VII

FUELS

The crude oils from which gasoline is derived occur in various parts of the world and manifest a variety of properties. Thus the "paraffine base," Pennsylvania and Ohio oils yield 60% to 70% of kerosene and lubricating oils, while the "asphaltum base," California, Ohlahoma, or Texas oil furnishes practically nothing of either of these products. It is much heavier than Pennsylvania oil, and Mexican oil is usually still heavier. Crude oils having an asphaltum base are heavy and dark-colored and when distilled down leave a black tarry residue. If a crude oil has a paraffine base it is lighter in weight and color, and the residue after distillation yields (by pressure and refrigeration) the white paraffine wax. Either kind of crude oil will yield good gasoline. A large proportion of the world's supply of crude petroleum comes from American wells. These variations are indicated by the density, which varies from a maximum of 50 degrees with Pennsylvania crude, down to 12 degrees or less with California crude. The lower the density, the less is the proportion of gasoline obtainable from the crude oil.

The density of liquids lighter than water (like fuel oils and their products) is obtained by the hydrometer reading. The specific gravity is the weight of the liquid as compared with the weight of an equal bulk of water. Hence, water would give an hydrometer reading of 10 degrees. Water weighs 8⅓ lbs. per gallon at normal temperature.

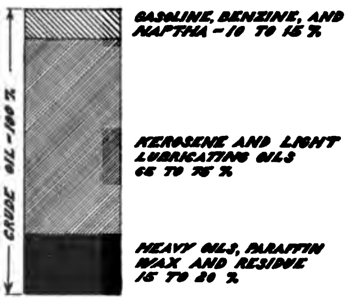


Fig. 40 — Composition of crude oil

Crude oils are too heavy and vicious for use as fuel in internal combustion engines without special preparatory treatment. They require heating and may liberate poisonous or explosive gases which are heavier than air. They contain, as impurities, free carbon, sulphur, silt and moisture, in widely varying proportions.

When crude oil is subject to moderate heat those of its constituents which have a low boiling point are boiled off. By condensing their vapors, highly inflammable gasoline is obtained.

After this a somewhat higher temperature may be applied and lower grade gasoline collected in a separate condenser. By successive increases of temperature, with separations of products condensed, a considerable series of products is derived.

It would be commercially inadmissible to treat crude oil with a view to deriving gasoline only. This process is called "fractional distillation," and is the basis of petroleum refining. As the temperature of distillation increases, the products become lighter, having a higher hydrometer reading and being less fluid and inflammable. Fig. 40 shows the composition of a sample of American crude oil.

AVERAGE FRACTIONATION OF CRUDE PETROLEUMS (Robinson)

American Oil

Constituent	Per cent. Obtained	Boiling Point, Deg. Fahr.	Hydrometer Reading, Deg.
Gasoline	0–10	32–265	58–107
Kerosene	12–55	300–700	44–49
Fuel oil (gas oil)	variable	.....	35
Lubricating oil	17½	.....	22–28
Paraffin and residue	2–10	.....	.....

Russian Oil

Constituent	Per cent. Obtained	Boiling Point, Deg. Fahr.	Hydrometer Reading, Deg.
Gasoline	5–16	.....	53–63
Kerosene	40–52	.....	33–41
Lubricating oil	3–40	.....	22–31
Residue (fuel oil)	10–15	.....	17–25

The boiling point of any liquid varies according to the pressure to which it is subjected. If the boilng temperature at atmospheric pressure is less than the resisting temperature, the liquid will vaporize until a pressure is created equal to that at which boiling occurs at the existing temperature. The lighter gasolines therefore are always boiling off from the crude oils which contain them. Loss and danger can be avoided only by confining such oils.

The proportions of the various products obtainable from refining any particular crude oil cannot be changed by the refiner. In getting 5% of gasoline, for example, say, he is compelled to accept 40% of kerosene. If the demand for kerosene is slight, while the demand for gasoline is brisk, he may have to sell the former at a loss and protect himself by charging an excessive price for gasoline. There is no such thing as "cost of production" chargeable against any one of the products. When any one is cheap, others must be

dear. If gasoline is cheap at any time it is because there is relatively a greater demand for other products. About 1903 kerosene was cheaper than gasoline in some sections. Recently it has been twice as costly.

The average gasoline consists mainly of carbon and hydrogen: From 83½ to 85 parts of the former to 15 to 15½ of the latter by weight. Good commercial gasoline should show an hydrometer reading between 67 degrees and 73 degrees. Grades down to 50 degrees are sometimes offered. They are, of course, not true gasoline, but may be used in warm weather without difficulty. This density is about the same as that of some of the best samples of Pennsylvania crude oil. At 68 degrees the specific gravity is 0.71. Since water weighs 8.33 lb. per gal., this gasoline weighs 5.91 lb. per gal. Petroleum products are always sold by bulk; the gallon or the 42-gal. barrel. It would be fairer if they were sold by weight.

It will be noted that some slight amounts of the lighter gasolines are obtained by distillation at temperatures as low as 32 degrees F.; i.e., without any heat at all. In fact as much as 1½% of some American crude oils will distill off at temperatures below 150 degrees F. These products are highly inflammable and dangerous. It is not always possible to market them. By blending them with rather light kerosene a substance is produced which may be regarded as gasoline, for it has the density of the latter. It has different properties, however, notably with respect to igniting point and vapor pressure.

Gasoline may be produced from natural gas by the combined effects of pressure and cooling. Improved methods of distillation increase the gasoline yield from crude oil, but usually at the cost of some impairment to quality.

Average gasoline must be supplied with air in the ratio 15 to 1 by weight for complete combustion. This means that 1 lb. of fuel requires 200 cu. ft. of air at 62 degrees F. Gasoline vapor weighs 0.24 lb. per cu. ft. at atmospheric pressure and 32 degrees F., or is about three times as heavy as air. About 50 cu. ft. of air are required to make a perfect combustible mixture with 1 cu. ft. of gasoline vapor. These ratios may be considerably varied without preventing ignition, but if varied the power and efficiency are influenced unfavorably. According to Lucke, limits are as follows:

	Ratio of Gasoline Vapor to Total Mixture, by Volume
86° Gasoline	0.0154 to 0.0476
71° Gasoline	0.0154 to 0.0476
65° Gasoline	0.0131 to 0.0476

If these limits are passed, the mixture will not ignite explosively (at atmospheric pressure, by electric spark). As has been shown, the best value is about $\frac{1}{50}$ or 0.02. A rich mixture causes failure to ignite less promptly than does a weak mixture.

The heat value of a fuel is expressed in British thermal units (B. t. u). One B. t. u. is the quantity of heat necessary to raise the temperature of 1 lb. of water 1° F. It is equivalent to 778 foot-pounds of mechanical energy. Since 1 horse-power = 33,000 foot-pounds per min., it also equal to 33,000 ÷ 778 = 42.42 B. t. u. per min. Average gasoline contains from 19000 to 21000 B. t. u. per lb. Thus for 68° gasoline, B. t. u. per lb. = 20970. The lighter the distillate the higher the heat value. One horse power is 42.42 B. t. u. per min. or 42.42 × 60 = 2545 B. t. u. per hr. The gasoline consumption of a perfect engine would be 2545 ÷ 20970 = 0.121 lb. per hour per horse-power. Actually it is four to seven times this or more, on account of the inefficiency of the engine. High compression — which follows low clearance — reduces the fuel consumption. The fuel consumed per mile depends on the traction force exerted, the efficiency of the engine and driving mechanism, and the speed.

If gasoline is used composed of 84 parts of carbon to 16 of hydrogen, by weight, about 15.22 lbs. of air will be the correct amount per lb. of fuel. More air will give more power, but at a sacrifice of efficiency. Suppose the truck to make 5 miles per gallon of gasoline. If the liquid fuel were stretched out along the road in a pipe, the tube of fuel containing one gallon or 231 cu. in. would be 5 miles or 316800 inches long, and its diameter would be about $\frac{1}{33}$ of an inch. A similar pipe full of air would contain 1130 cu. ft., or the diameter would be 2.8 inches. This illustrates the point that most of what goes into the cylinder under any condition is nothing but air.

Since 1 lb. of gasoline produces about 200 cu. ft. of combustible mixture, the mixture contains about 20970 ÷ 200 = 105 B. t. u. per cu. ft. This is reduced if the temperature is higher than 62 degrees F., because 200 cu. ft. at 62 degrees F. will occupy a larger volume at higher temperatures.

Efforts are constantly being made to find acceptable substitutes for gasoline. The most important substitutes may be grouped in three classes: Lower grade distillates, including kerosene; alcohol; and coal distillation products, such as benzol. The study of substitutes has until recently been carried on much more thoroughly in Europe than in this country, because there are no readily accessible supplies of gasoline from the commercial centers of the continent.

Kerosene has very nearly the same percentage composition as gasoline, but its density being greater, its heat value is less. It requires more air for combustion, and the heat value per cu. ft. of combustible mixture is less. The lower heat value is not an objection, in fact, it is in one way an advantage. Low heat values mean a high ignition temperature. This permits of more compression without danger of preignition, and high compression increases both power and efficiency. However, a high ignition temperature does itself introduce difficulties.

The essential objection to kerosene is the difficulty of vaporizing it. The table shows that its boiling point is 300° F. or more. Gasoline may be vaporized either by pure evaporation in a slow current of warm air, or by spray-injection. Kerosene needs heat. This may be supplied externally, at the carburetor; or the fuel may be delivered to the cylinder in liquid form by a pump and vaporized by contact with a hot (unjacketed) cap or plate forming a part of the cylinder. This is the method of the Hornsby-Akroyd stationary engine, but the timing of ignition is uncertain, especially under variable loads. For motor cars, carburetor heating is more promising.

Kerosene is not necessarily more apt to form carbon deposits. These will result from any blended fuel in which the free carbon of the heavier constituents has not been thoroughly filtered out, or from any fuel at all under appropriate conditions of carburation and cooling.

Alcohol as a fuel has had considerable attention. There are two kinds, **methyl** or wood alcohol, and **ethyl** or grain alcohol. The former contains half the carbon and two-thirds the hydrogen of the latter. It has only about three-fourths the heat value and requires less air for combustion. Unlike petroleum distillates both of the alcohols contain oxygen. Commercial alcohols always contain water. This does not destroy their value as fuels. The heat value of pure ethyl alcohol may be taken at 12800 B. t. u. per lb.

One cu. ft. of alcohol vapor requires 14½ cu. ft. of air for complete combustion. It will ignite when the air volume is anywhere between 7 and 25 cu. ft. If the air supply is seriously deficient, the combustion products will contain acetic acid, which causes rusting and corrosion. The igniting temperature of alcohol vapor at atmospheric pressure is 950 degrees F. The alcohols are intermediate between gasoline and kerosene in their readiness of vaporization, and methyl alcohol is particularly close to gasoline in its vaporizing properties. Moderate heating at the carburetor is required in cold

weather. Higher compression is necessary than with gasoline for the same power and efficiency, and the engine must be specially designed for such high compression. Tests have shown that where 70 lbs. compression pressure was used for both fuels, the alcohol engine consumed 50% more fuel than that burning gasoline. By raising the compression of the former engine to 180 lbs., its fuel consumption became the same as that of the gasoline engine: 0.10 gallons per hour per horse-power. Unfortunately the present methods for distillation of alcohol from vegetable substances have not yet produced that fuel at a price competitive with that of gasoline.

Benzol is a by-product of the distillation of soft coal, for the manufacture of coal gas or coke. It appears both in the gas and in the liquid tar, and is derived only when by-products or retort ovens are used. It ignites at 970 degrees F. at atmosphere pressure. Its specific gravity is 0.88 and its heat value about 18000 B. t. u. per lb. About 13½ lbs. of air are required for combustion of 1 lb. of benzol, or about 36 cu. ft. of air for 1 cu. ft. of benzol. Ignition is possible with 15 to 37 volumes of air, but weak mixtures are very uncertain. Benzol has been used in three ways. While somewhat less volatile than gasoline, it has been vaporized in an ordinary caruberetor, after starting on gasoline. By adding benzol to alcohol there is less danger of corrosion from acetic acid formation. In Europe, a mixture of equal parts of benzol and alcohol has frequently been employed as a motor fuel. The mixture had a heat value of 14200 B. t. u. per lb. Commercial benzol has been charged with excessive carbon formation, but so has commercial gasoline of the present day.

There seems to be little possibility of the direct use of crude oil, coal tar (a by-product from coal-gas distillation) or tar oil (by-product from tar distillation) in the cylinders of motor-car engines. Even in stationary engines of the hot-cap type they have been unsatisfactory. Extremely high compression and still higher fuel-injection pressures, usually complicated by an air blast, have thus far been necessary. The engines have been heavy and costly and in many instances unreliable. Kerosene is the most promising cheaper fuel, but the kerosene problem will not be solved until the starting problem, as well as the running problem, is solved. There seems to be no good ground for apprehension that the substitution of kerosene will leave us where we are now, as far as cost is concerned. The yield of kerosene is very much greater than that of high-grade gasoline. In fact, kerosene is simply low-grade gasoline. Circumstances are compelling the use of lower and lower grades, so that a

gradual approximation to kerosene as fuel seems both the most probable and the easiest direction for progress. The necessary modifications of equipment have in a measure been already anticipated by such devices as water-jacketed and hot-air-jacketed carburetors, etc.

CHAPTER VIII

ELEMENTS OF CARBURETION

Pure gasoline vapor must be combined with oxygen in order to render it inflammable. The simplest manner of effecting this is to mix air with gasoline. When the correct proportions are obtained the oxygen supplied by the air will be sufficient to result in the complete combustion of the gasoline vapor without a surplus of either of the ingredients. This mixing is called carburetion and the air is said to be carbureted.

The carburetor is a metering device whose function is to blend mechanically a liquid fuel with a certain amount of air to produce as nearly a homogeneous mixture as possible and in such proportion as will result in as perfect an explosive mixture as can be obtained.

With a liquid fuel such as gasoline it is difficult to obtain this perfect mixture especially with low-test gasoline. If it were possible to transform a liquid fuel into its vapor, the vapor would act as a gas and would mix easily with the air to form a homogeneous mixture. The carburetor should be so designed as to atomize the fuel that is to break it up into as small particles as possible so every minute particle of the fuel is surrounded by the correct proportion of air as it enters the inlet manifold of the engine. To facilitate the vaporization of these minute particles of fuel it is advisable to heat the air taken into the carburetor.

There is a range of proportions of air to vapor for a given fuel between which combustions will result. This range extends from that proportion known as the **upper limit of combustion** to that known as the **lower limit of combustion.** The upper limit is reached when the ratio of air to vapor is a maximum at which combustion will take place, any further addition in air rendering the mixture noncombustible. The lower limit is reached when the ratio of air to vapor is a minimum at which combustion will take place, any decrease in air below this point producing a noncombustible mixture. It should be remembered that the limits of combustion are dependent upon the temperature and pressure.

The limits of combustion of gasoline (70° Sp. Gr.) can be taken approximately as follows: Lower limit, 7 parts air (by weight) to 1

part gasoline; upper limit, 20 parts air to 1 part gasoline. Under given temperature and pressure the ratio at which a combustible mixture will burn depends upon the ratio of air to vapor. This rate of burning is known as the **rate of flame propagation** and it is desirable to obtain a mixture whose rate of flame propagation is a maximum because the expansion will depend upon the rapidity with which the entire mixture is completely burned.

Rich mixtures have a greater proportion of fuel vapor and are slow burning and sluggish. They also cause carbon to be deposited in the combustion space because of their incomplete combustion. Mixtures that have too great a proportion of air are very erratic in their combustion. The mixture in the cylinders is often formed in layers and as each layer burns independently of the other the rate of burning is slow. The term **lean mixture** is often used to designate not only this type of mixture but also those which have not reached the upper limit. These mixtures have a high rate of flame propagation. When mixtures are too lean they cause misfiring of the engine and also cause back-firing into the carburetor.

A carburetor must be constructed to maintain the proper proportions of gasoline and air under all conditions. To accomplish this several designs and principles have been evolved which will be discussed in the following chapters. Types of carburetors which are not commonly used will not be discussed because the principle upon which they are based has not proven satisfactory for motor vehicles.

Before taking up any of these types it is necessary to study the basic principles underlying carburetion. These will be most clearly understood when applied to a simple carburetor of the spray nozzle type. The gasoline supply from the storage tank enters the float chamber *F* of the carburetor and as the gasoline level rises the float presses against the levers at the top of the float chamber (Fig. 41). These levers are pivoted so that their outer ends are raised by the float. Their inner ends working in a collar or recess, press the float needle valve downward into its seat. This shuts off the supply of gasoline when the level in the float chamber has reached the proper height. The height at which this gasoline

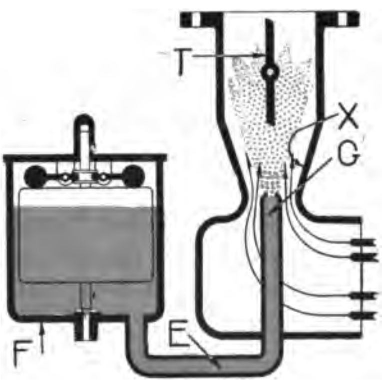


Fig. 41 — Simple carburetor

should be maintained is governed by the nozzle or jet G. The level must stand approximately $\frac{1}{16}$ inch below the top of this nozzle. The gasoline is fed to the nozzle G from the float chamber through the pipe E. The inlet valve being open when the piston moves outward in the cylinder on its suction stroke, air will be drawn through the carburetor, as indicated by the arrows in Fig. 41, passing the nozzle on its way to the cylinders. The suction created by the rush of air past the spray nozzle causes the gasoline to be delivered to the mixing chamber in a fine spray. Since the suction depends upon the velocity of the air passing the nozzle, a Venturi tube X is used.

A Venturi tube is a tube which is narrower at the center so that the area through which the air must pass is considerably decreased. As the same amount of air must pass through every point in the tube its velocity will be the greatest at the narrowest point. The more this area is reduced the greater will be the velocity of the air and the suction will be proportionally increased.

The spray nozzle should be located where the suction is greatest which is just above the narrowest part of the Venturi tube. The spray of gasoline from the nozzle and the air entering through the Venturi tube are mixed together in the mixing chamber, that portion of the tube immediately above the spray nozzle. This produces a combustible mixture which passes through the intake manifold into the cylinders.

The speed of the engine is controlled by the use of the throttle T which is a form of damper placed between the mixing chamber and intake manifold. The more the throttle is closed the greater will be the obstacle placed in this passage and the greater will be the opposition to the filling of the cylinder at each stroke. This gives a less powerful impulse to the piston and the engine's speed is correspondingly reduced.

As the throttle is opened the speed of the engine increases and with wide open throttle attains its maximum speed which for this discussion will be assumed to be 1600 R .P. M. The cylinder fills as freely as possible and a large quantity of air passes through the carburetor while the gasoline jet delivers its maximum.

As the load on the engine is increased as will be the case when a hill is encountered, the speed is gradually diminished, say to 400 R. P. M. It is obvious that the air does not pass through the carburetor with the same velocity as before and the suction is greatly reduced, although the throttle is still wide open. It is evident the throttle does not wholly control the speed of the engine; the load is also a factor that must be considered. In actual test with wide

open throttle the engine suction has decreased over nine times between 1600 R. P. M. and 400 R. P. M. The throttle is simply a means to prevent the engine from pulling in a full charge of mixture each suction stroke and thus regulates its power.

As the speed of the engine increases the suction increases. The flow of liquids is governed by definite laws and the flow from a jet increases under suction faster than the corresponding flow of air. With a simple construction of nozzle the mixture becomes richer as the speed increases. As it is essential to have practically the same proportions of air and gasoline at all speeds it is necessary to construct the carburetor to maintain this proportion as the suction increases.

To overcome rich mixtures the carburetor must be adjustable so that less gasoline or more air will be supplied. The gasoline supply is controlled by the size of the spray nozzle opening. For a given

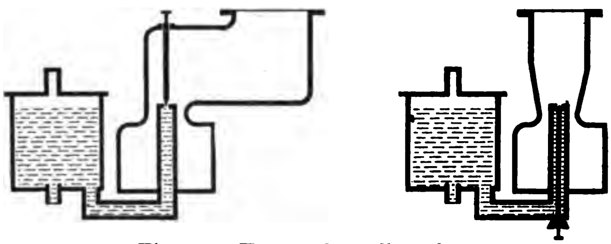


Fig. 42 — Types of needle valves

suction the quantity of gasoline delivered varies directly as the cross-sectional area at the nozzle. In some carburetors the nozzle, which is of fixed size, may be replaced by a smaller or larger nozzle depending upon the regulation desired.

In other carburetors the opening at the nozzle is adjustable by means of a needle valve (Fig. 42). As the needle is screwed into its seat the nozzle area is reduced resulting in leaner mixtures.

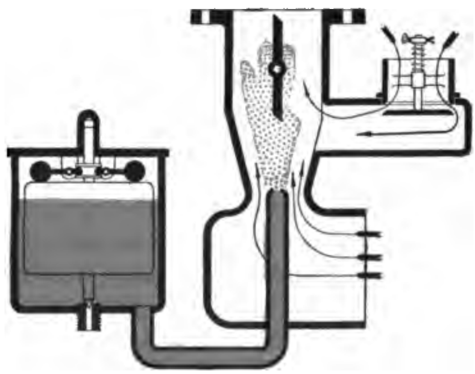


Fig. 43 — Auxiliary air carburetor

The air supply may be controlled by employing an automatic air valve (Fig. 43). This consists of a valve held in its seat by a spring whose tension is adjustable. This valve is opened automatically by atmospheric pressure which

will overcome the tension of the spring allowing air to enter the mixing chamber. As the tension in the spring is increased greater suction will be required to open the valve regulating the point at which the valve opens and the amount it opens.

The auxiliary air entering the mixing chamber does not pass through the Venturi tube hence it dilutes the rich mixture resulting from the increased suction. In this manner the proportions of air and gasoline are kept constant at variable speeds.

Precautions When Adjusting Carburetor. — Before attempting to put a carburetor in proper adjustment certain conditions must prevail.

1. The engine must be warm.
2. The adjustment must be made under actual operating conditions.
3. There must be no leaks allowing air which does not pass through the carburetor to enter the combustion space.
4. All choking devices must be wide open.
5. All gasoline passages must be free from obstructions.
6. The ignition system must be properly timed and in working order.

In making carburetor adjustments it is desirable to obtain as lean a mixture as will give proper results. Hence, it is imperative first to diminish the proportions of gasoline to air until so lean a mixture is obtained that missing of the engine and possibly back-firing in the carburetor results. The proportion should then be **gradually** increased until the missing is overcome and the engine runs smoothly.

When making any changes in adjustment it is necessary that only slight changes be made at a time. After every change of adjustment sufficient time must be given for this change to effect the operation of the engine before further changes are made. This will eliminate any possibility of making unnecessary changes. The greatest care must be observed in this respect when overcoming a lean mixture since a mixture richer than necessary may result. This would not be noticed in the running of the engine but would increase the fuel consumption materially.

Carbon monoxide, a deadly poisonous gas, is present in the exhaust of gasoline engines. Increasing the proportion of gasoline to air in the mixture increases the amount of carbon monoxide given off at the exhaust pipe. Because of the presence of carbon monoxide it is very dangerous to run the engine for any length of time while the car is in a small closed garage. If the doors and windows are open the danger is very much lessened, but it is far safer if an

adjustment of the carburetor is being made to run the car outside.

Serious personal injury may be caused by the presence of carbon monoxide in a garage if the percentage of it in the air is greater than a very small fraction of one per cent. Unconsciousness may result without warning. It is reported that no indication of danger is given by personal discomfort until too late. Deaths resulting from the presence of carbon monoxide in garages have been reported.

During the final test of all motor apparatus by the manufacturer the carburetor is very carefully adjusted and this adjustment **should not be changed unless it is absolutely necessary** because of greatly changed climatic conditions or grade of fuel used. After the carburetor is adjusted to operate under these conditions there should be no necessity for further change.

Engine troubles arise from many sources and it is very seldom that the trouble is due to the carburetor adjustment. It must be borne in mind that a properly adjusted carburetor cannot get out of adjustment unless tampered with. It is the tendency of inexperienced men to adjust the carburetor no matter what the trouble, without first endeavoring to locate the real difficulty. This leads to the adjusting devices becoming worn and inaccurate. Make it an inflexible rule to try to locate engine troubles at all other possible sources before touching the carburetor.

In case the suction through the carburetor is suddenly increased by quickly opening the throttle, the air, being lighter than gasoline, will respond almost instantly and its flow will be accelerated very suddenly. The gasoline particles owing to that characteristic known as " inertia," will not respond so rapidly due to their heavier weight and the flow of gasoline will not accelerate as rapidly as the air. This will result in the air rushing ahead of the gasoline particles and the proportion of air to gasoline will be greater until the inertia has been overcome and the gasoline particles have responded completely to the increased suction. This condition will take place unless some provision is made against it. That is, a sudden opening of the throttle will tend to produce a very lean mixture at the engine due to the lagging of the gasoline. A lean mixture at this time, when accleration is desired, will be detrimental. It is at this particular time that additional gasoline is most desired in order to compensate for this lagging and maintain the proper mixture at the engine. The device which accomplishes this result is known as an " accelerating well." The construction or arrangement of this device will be explained as each type of carburetor is taken up.

A rich mixture is required when starting an engine, especially when cold. The additional gasoline may be supplied in several

ways; by priming through the priming cocks, by "flooding" the carburetor, by the use of chokes, or by a dash control which increases the gasoline supply temporarily.

The practice of priming should not be resorted to unless all other methods fail, since the continued addition of liquid gasoline to the cylinders cuts the lubricant causing loss of compression and permits the gasoline to run past the pistons into the crank case. The result of over-priming makes it almost impossible to start the engine because of the abnormally rich mixture obtained. If an explosion does result the power will not be sufficient to rotate the engine until another power impulse is obtained.

Pet cocks are made with a cup which will hold sufficient gasoline for proper priming. This cup should be filled, the cock opened, and again closed. The common practice of priming without regard to the amount of gasoline used generally results in over-priming. Before starting an engine which has been over-primed the pet cocks should be opened and the engine cranked until the piston and cylinder walls have been lubricated. Turning the engine over for some time also frees the combustion space of the over-rich mixture. This must be done as the liquid gasoline adheres to the piston and cylinder walls enriching each incoming charge.

Flooding the carburetor causes the float chamber to be filled with gasoline above the level at which it ordinarily stands. Gasoline will overflow from the spray nozzle by gravity and be picked up by the primary air and carried into the cylinders.

Rich mixtures for starting may also be obtained by the use of chokes. These are placed in the air passages making it difficult to draw air, the suction being satisfied by an increased amount of gasoline vapor. Choking devices are provided on some carburetors to cut down the supply of air until the engine is heated.

All liquids vaporize when heated sufficiently and while gasoline will vaporize at ordinary temperatures, increased heat improves this vaporization. This tends to reduce the percentage of liquid gasoline in the mixing chamber causing a more intimate combination of the air and gas. This heat may be obtained by passing air heated by the cylinder or exhaust pipe through the carburetor, by water-jacketing the mixing chamber of the carburetor, by water-jacketing the inlet manifold, or by combining the inlet and exhaust manifolds so that the exhaust gases heat the incoming charge.

There are two common types of float chambers; the concentric in which the float chamber is placed around the Venturi tube and is concentric with it, the eccentric in which the float chamber is placed by the side of the Venturi tube.

Figure 44 shows an eccentric type float chamber and the normal gasoline level is shown by the line in *A*. When the carburetor is tilted due to the car's ascending or descending a grade the level will be changed as shown in *B* or *C*. This causes too much or too little

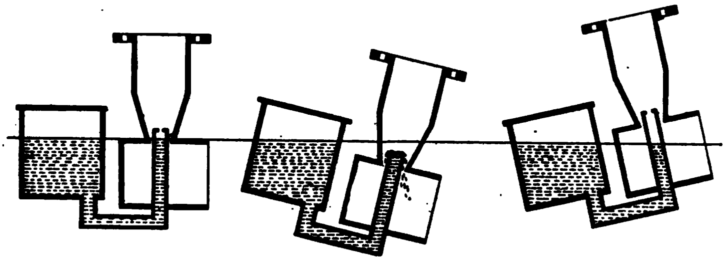


Fig. 44 — Effect of grades on eccentric type carburetor

gasoline to be supplied by the nozzle giving imperfect mixtures. To prevent lean mixtures when ascending grades a carburetor with this type of float chamber should be attached with the float chamber towards the radiator. This difficulty will not be experienced with a concentric float type of carburetor. The level at the

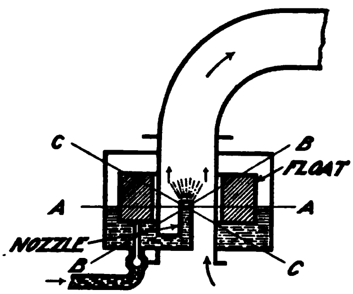


Fig. 45 — Effect of grades on concentric type carburetor

nozzle always remains constant as shown in Fig. 45 by the different levels *A-A, B-B* and *C-C*. This accounts for the usage of concentric float carburetors on motor-cycles, tractors, or other motor vehicles which are not designed for the ordinary road work.

Governors. — In order automatically to limit both the vehicle and engine speed at all times, a governor is provided. It consists of a grid or butterfly valve in the inlet manifold controlled by the action of movable weights attached by levers to the driven shaft and valve mechanism. Centrifugal force which results from whirling

the weights around the shaft causes them to pull away. This action moves the valves in the intake manifold cutting down the supply of gas.

The position of these weights will depend upon the speed of the engine and at approximately 1200 R. P. M. the gas supply will be cut off, restricting the engine and consequently the vehicle speed. This governing limits the speed of the machine to about 15 miles per hour.

The drive is through a flexible shaft. It is driven by a set of gears from the cam shaft or by the flywheel. An adjustment is provided for varying the setting of the governor.

CHAPTER IX

CARBURETORS

The operation and adjustment of the various types of carburetors most commonly used will be outlined giving the particular points in which they vary.

SCHEBLER — MODEL "E"

This carburetor is a concentric float auxiliary air type and is a very simple carburetor. The primary air inlet is through an air bend at the bottom of the carburetor passing the spray nozzle and the auxiliary air inlet, controlled by the usual type of valve, is provided at the top of the mixing chamber. The spray nozzle is regulated by the needle valve (Fig. 46).

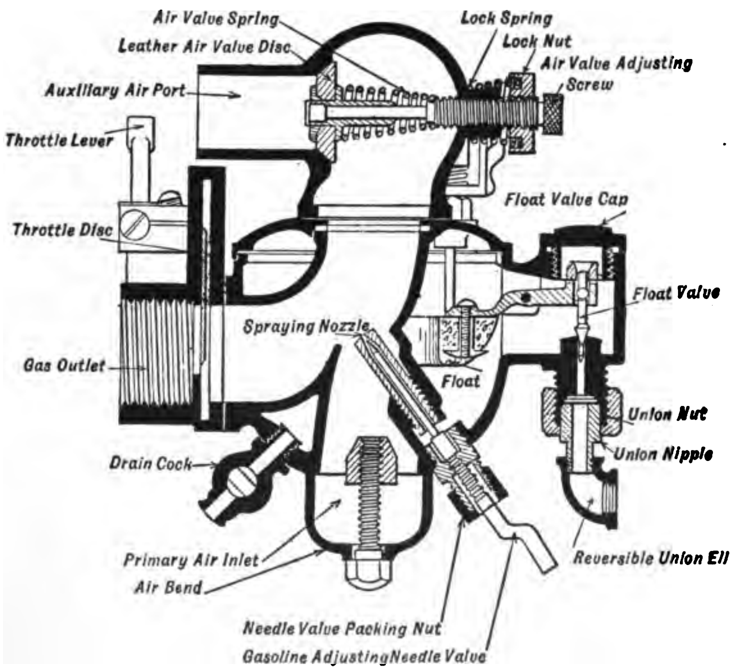


Fig. 46 — Schebler model E

Low Speed Adjustment. — Have the auxiliary air valve spring tension tight, then adjust by the needle valve turning to the right until the mixture is too lean, and then turn gradually to the left until the missing of the engine is eliminated and the engine runs smoothly.

High Speed Adjustment. — Release the tension on the auxiliary air valve spring until so much air is supplied that missing of the engine results, and then tighten the spring tension until the engine runs smoothly With these settings the increasingly rich mixture of the primary should be compensated for by the extra auxiliary air at all speeds.

The Schebler — Model "H"

This carburetor is for motor-cycle use and is of the auxiliary air type having a "lift needle valve." The supply of gasoline is controlled by a needle *E* and cam adjustment, which insures the proper amount of gasoline at all speeds. As the throttle is opened the needle rises from its seat.

An air elbow is attached to the primary air passage of the carburetor so that it can be turned to any convenient angle in order to draw warm air off the cylinders (Fig. 47).

Low Speed Adjustment. — See that the leather air valve *A* seats lightly and then turn knurled button *I* to the right until the needle *E* seats in the spray nozzle cutting off the flow of gasoline. Now turn *I* to the left about three turns and open low speed air adjusting screw *L* about three turns and then open the throttle about half way to start the engine. After starting the engine close the throttle and turn needle valve adjusting screw *I* to the right until the mixture becomes so lean that the engine back-fires or misses. Then turn adjusting nut *I* to the left slowly, notch by notch, until the engine runs smoothly. If, with this low speed adjustment, the engine runs too fast turn low speed adjusting screw *L* to the right thus increasing the size of the throttle opening.

High Speed Adjustment. — The carburetor is now ready for high speed adjustment and the throttle should be opened and the spark advanced. The machine should be run at high speed on the road. The adjustment is now made by the pointer *Z* which, as it moves from *1* toward *3*, increase the supply of gas as it allows the needle valve *E* to be raised higher out of the nozzle. Moving the indicator *Z* from *3* towards *1* cuts down the supply of gasoline as it raises the cam and does not allow the needle to move as far out of the nozzle. When the indicator reaches the correct point

the engine runs without missing or back-firing. If, when lever *Z* is turned to *3* the mixture is still too lean, causing the engine to miss and back-fire, increase the tension of auxiliary air valve spring by turning adjusting screw *12* to the left.

The air lever on the side of the mixing chamber should be opened when extremely high speed is desired. Be sure to shut this port before the engine is stopped because difficulty will be experienced in starting if this port is left open.

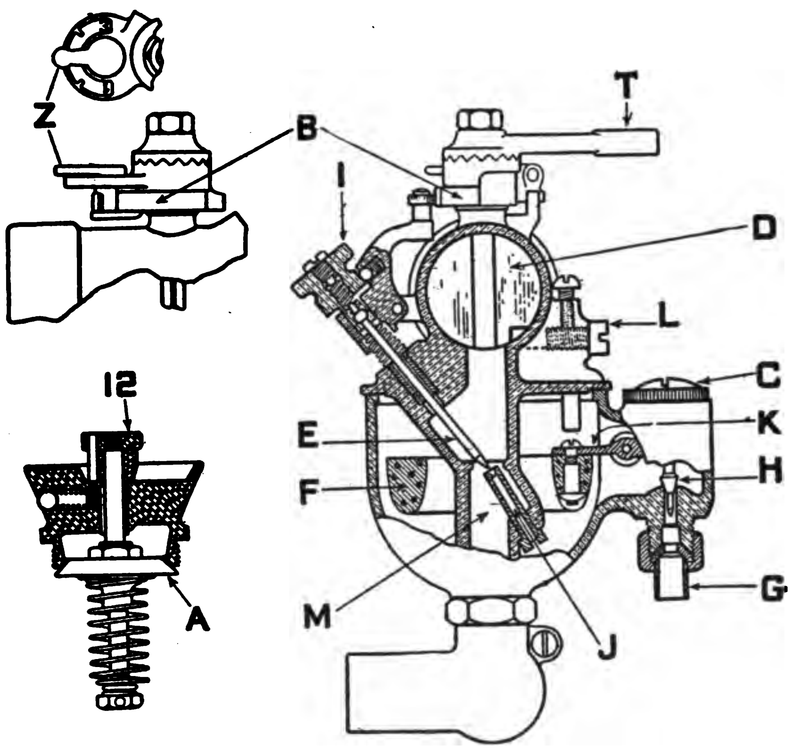


Fig. 47 — Schebler model H

Starting. — To facilitate easy starting of the engine pull out the knurled button *12* and turn to the right or left so that it cannot fall back in the recess. This tightens the spring on the auxiliary air valve preventing a large quantity of cold air rushing past this valve. The cold air admitted to the carburetor will come only through the primary air passage past the nozzle insuring a rich mixture which will facilitate easy starting.

After the engine starts the knurled button *12* should be turned back to release the spring tension. Just after the engine starts it

will often be inclined to back-fire which is caused by the parts being cold. In this case the knurled button *12* should be dropped into recess marked *2* until the engine warms up.

Kingston — Model "E"

This is an auxiliary air type of carburetor with concentric float chamber. The construction is shown in Fig. 48.

The principle involved, while simple, requires some explanation. Gasoline is admitted at connection *24* and continues to flow until valve *22* is seated due to the proper height of gasoline being obtained. From the float chamber the gasoline passes to the spray nozzle

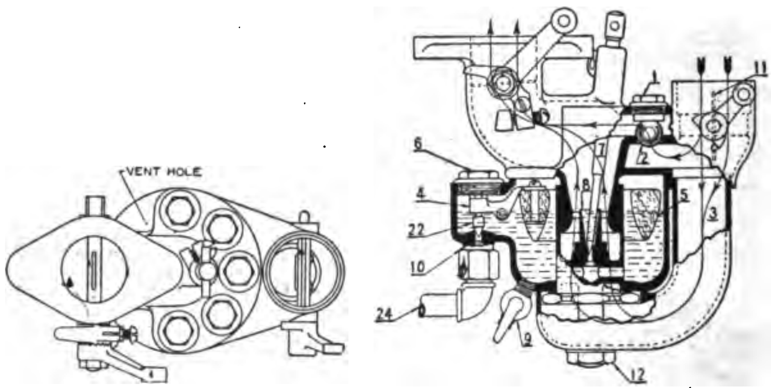


Fig. 48 — Kingston model E

the shape of which should be particularly noticed as it forms a cup around the needle valve above its seat, the level being $\frac{1}{32}$ inch below the top of the cup.

When starting this excess gasoline is drawn up with the primary air and furnishes a very rich mixture. As the speed increases this cup is emptied, the supply being drawn from and regulated by the adjustment of needle valve *7* at its seat.

Both primary and auxiliary air are drawn from a common source passing controller or choke *11*. The primary air passes down the primary air passage *3* and up through the Venturi tube.

The auxiliary air in this carburetor is not controlled by a valve but by five balls *2* which are lifted from their seats by suction. These balls are seated at different depths and as the suction increases, they permit a greater amount of air to pass by them. There is no adjustment, their action being automatic and arranged by the manufacturer.

The only adjustment on this carburetor is the needle valve which should be set to give the proper results at the speed at which the apparatus will be habitually used. The needle valve when turned to the right, gives leaner mixtures and when turned to the left gives richer mixtures. The action of the auxiliary air should compensate for any change in speed.

Packard

This carburetor is of the auxiliary air type with eccentric float chamber. The gasoline flows into the float chamber through a needle valve and then into the nozzle *40* (Fig. 49).

The mixing chamber is surrounded by a water jacket through which passes warm water taken from the water circulation system. This maintains a uniform temperature and insures efficiency in mixing the sprayed gasoline with air. The air has two paths through which it can enter the carburetor, the primary air inlet *33* and the auxiliary air inlet *26*. The primary air in passing the nozzle picks up the gasoline. The auxiliary air does not pass the nozzle and therefore enters the mixing chamber as pure air.

It is important that the mixture of air and gasoline be kept at a constant proportion. Although the primary air inlet valve is large enough to supply air for all conditions, the proportion of air and gas does not remain constant as the suction increases, therefore auxiliary air is necessary. The auxiliary air inlet valve is controlled by springs so that while the valve opens slightly at low speed the increased suction at high speed opens it still more, admitting a greater amount of air, thus compensating for the rich mixture through the primary.

The primary air intake is from around the outside of the exhaust pipe. This provides a supply of warm air which prevents condensation in the carburetor and in cold weather materially assists in the vaporization of the gasoline. There is a regulator *30* so that the proportion of warm and cold air may be regulated.

Auxiliary Air Valve. — The valve is controlled by the tension of two springs one within the other. The tension of the springs is regulated by a wedge underneath them. This wedge is connected to the control board and when it is moved towards the word " gas " the tension of the springs is increased causing richer mixtures. This assists in starting, especially in cold weather and the lever should be kept more to the side " gas " than " air " until the engine warms up. This is the only regulation on this carburetor.

To further facilitate starting in cold weather there are chokes in both primary and auxiliary air intakes.

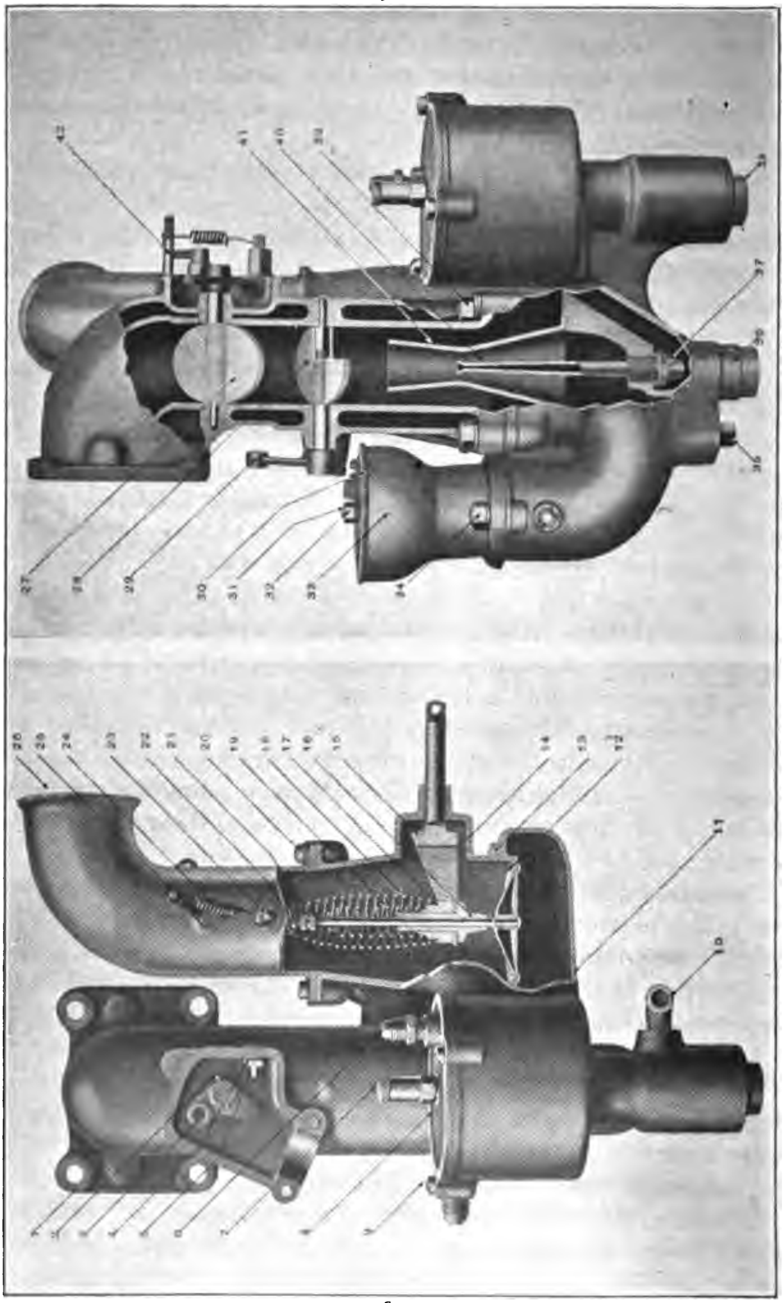


Fig. 49 — Packard carburetor

Peerless

This carburetor is of the auxiliary air type with eccentric float chamber (Fig. 50). The gasoline enters the float chamber passing through the screen *1107*. The level at which the gasoline is maintained in the float chamber is controlled by the float *1100* which operates the levers *1096* which in turn operate the needle valve *1101*. From the float chamber the gasoline passes directly to the nozzle *1110* which supplies gasoline to the mixing chamber.

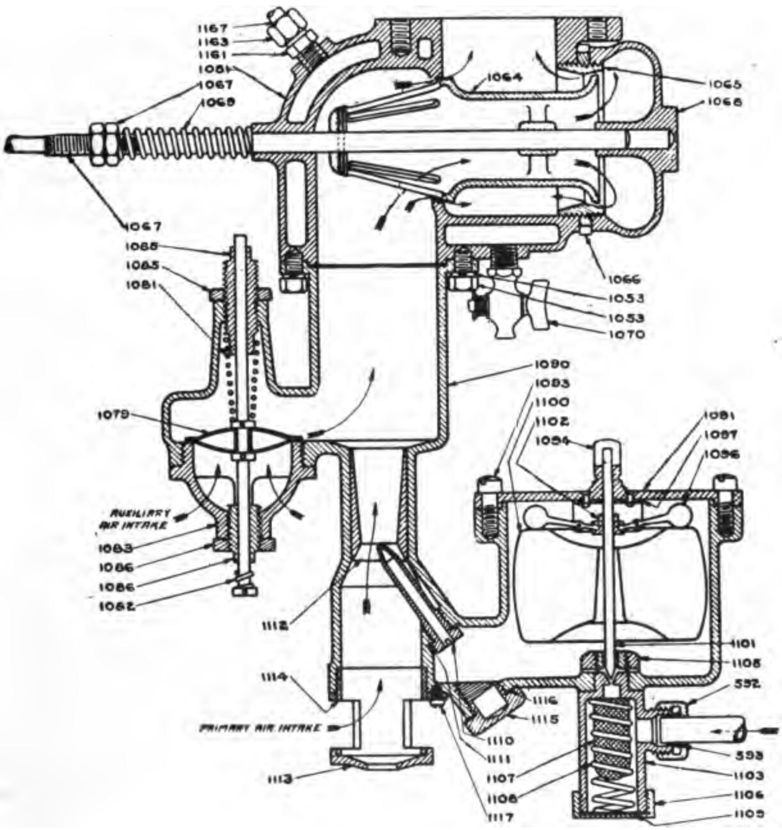


Fig. 50 — Peerless carburetor

Air enters the mixing chamber from two sources: the primary air entering at the primary air intake, passing the nozzle located at the center of the Venturi tube *1112*, picking up gasoline from the spray nozzle; the auxiliary air enters at the automatic air intake valve *1079* which is held in its seat by spring *1081*. The auxiliary

air enters the mixing chamber as pure air compensating for the rich mixture from the primary at high speed.

The mixing chamber is water jacketed which assists materially in vaporizing the gasoline and producing a more nearly homogeneous mixture.

The throttle is not of the usual butterfly construction, but consists of a valve having two seats. Before leaving the factory the seat *1065* is so adjusted that it will allow the proper amount of mixture to enter the cylinders when idling. The throttle *1064* is controlled by the throttle lever at the top of the steering column or by the accelerator pedal.

To adjust this carburetor the tension on the auxiliary air valve spring is changed. When nut *1085* is turned to the right, it increases the tension on the spring, thus reducing the amount of auxiliary air entering the mixing chamber for a given amount of suction causing the mixtures to become richer. When nut *1085* is turned to the left it weakens the tension on the spring, thus causing leaner mixtures.

To limit the maximum amount that the auxiliary air valve can open, an adjusting nut *1086* is placed on the lower side of the auxiliary air valve. By turning this to the left it will limit the maximum amount that the valve can open, thereby reducing the amount of air which enters at high speed. This adjustment should be made so that it does not effect the operation at any point except extremely high speed.

Pierce-Arrow

This carburetor (Fig. 51) is of the auxiliary air type with eccentric float chamber. Gasoline enters the float chamber from the tank, the level being controlled in the usual way. Valve *P* is operated by levers *M* which in turn are operated by the float. From the float chamber gasoline passes direct to the nozzle A^1. The primary air enters through the tube K^1, passing through the small Venturi tube L^1, picking up gasoline from the nozzle, and carrying it to the mixing chamber *L*. The auxiliary air is admitted through the carefully calibrated reed valves Q^1 and N^1. There is no method of regulating auxiliary air. The only regulation on this carburetor affecting the mixture is by the needle valve D^1. When screwed to the right it will give leaner mixtures and when screwed to the left it will give richer mixtures.

This carburetor is equipped with an adjustment for regulating the temperature of the air passing through the primary air inlet. Cold air regulator *I* is located at the rear of the carburetor; in warm

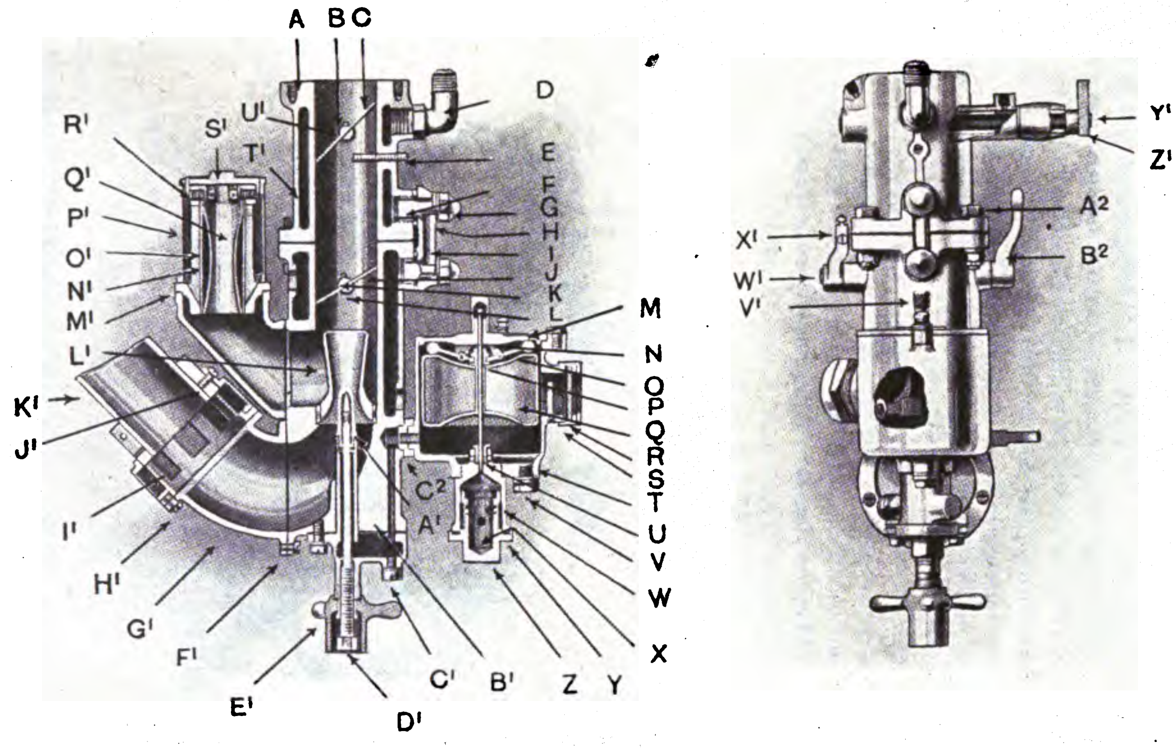


Fig. 51 — Pierce-Arrow carburetor

air regulator I is located at the rear of the carburetor; in warm weather the pointer of the regulator should be set to read "open," in cold weather it should be set to read " closed." Any intermediate adjustments can be made according to the temperature. There is also a hot water jacket T^1 around the mixing chamber. It is connected by pipe D from the carburetor to the outlet water pipe and is equipped with a cock. In warm weather this may be closed partially or entirely. By the use of these two adjustments incorrect mixtures encountered because of the lower grades of gasoline can be overcome as vaporization depends upon temperature.

Stromberg — Model " G "

This is an auxiliary air type of carburetor with eccentric float chamber. The gasoline enters the float chamber and passes to the two nozzles C and J.

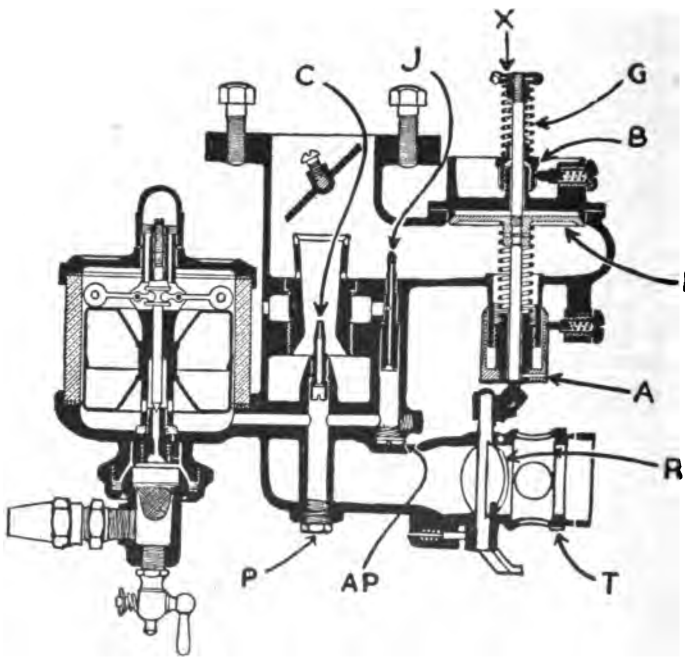


Fig. 52 — Stromberg model G

When the engine is idling air is drawn through the primary intake, passing around the primary nozzle C from which a jet of gasoline is spraying. Under load the air valve E allows additional air to be sucked in past the auxiliary nozzle J, producing a mixture which

unites with the primary mixture formed in the Venturi tube and passes by the throttle valve to the inlet manifold.

There are only two simple adjustments that ever need attention: *A* the low speed adjusting nut and *B* the high speed adjusting nut (Fig. 52). To adjust this carburetor proceed as follows: With the engine at rest set the high speed nut *B* so that there is at least $\frac{1}{16}$ of an inch clearance between the spring *G* and the nut *X* above it. **This is imperative.** Set the low speed nut *A* so that the air valve *E* is seated lightly.

Start the engine, first closing the choke valve *R* in the air horn by the control provided. Open this as soon as the engine starts and keep open while engine is running. If the engine does not start on the third or fourth turn of the crank open this valve and engine should then run.

Low Speed. — Do not adjust carburetor until engine is thoroughly warmed up. When engine is warm and with spark retarded, adjust nut *A* up or down until engine runs smoothly at low speed. To determine proper adjustment open the air valve with finger by depressing *X* slightly. If this causes the engine to speed up noticeably it indicates too rich a mixture and *A* should be turned down, notch by notch. If this causes the engine to die suddenly when slightly opening the air valve it indicates too lean a mixture, and *A* should be turned up until this is overcome. Once properly set for idling do not change this adjustment when making the high speed adjustment.

High Speed. — Advance the spark to the normal position and open the throttle gradually. If the engine back-fires through the carburetor it is a positive indication of too lean a mixture and nut *B* should be turned up notch by notch until this is overcome.

If the mixture is too rich as indicated by "galloping" of the engine and heavy black smoke from the exhaust, turn *B* down until the engine operates properly. A further test for the correct mixture at high speed can be made by depressing the air valve when the engine is running at this speed. If the engine speeds up it indicates too rich a mixture, if the engine runs slower, too lean a mixture.

Turning either adjusting nut up means a richer mixture or more gasoline; down means a leaner mixture or more air.

To Find Proper Nozzle Size. — Carburetors are equipped with the proper size nozzle before leaving the factory and no changes should be made unless absolutely necessary. Before changing examine all manifold and valve head connections for air leaks. It

is absolutely impossible to make the carburetor operate properly if there are any leaks in the engine.

Double Jet Type. — If after following the instructions given for adjustment with the engine running idle at low speed the air valve *E* remains tightly seated, it indicates too small a primary nozzle *C* and a larger one should be substituted.

If with the proper adjustment and after stopping the engine the air valve *E* hangs off the seat the primary nozzle is too large and a smaller one should be used.

To change primary nozzle remove pet cock or plug at *P*, insert screwdriver and unscrew nozzle.

If the mixture on low speed is correct but to get the proper high speed adjustment it is necessary to turn nut *B* up so far that the spring *G* is in contact with *X* above it, after the engine is shut down, it indicates that the auxiliary nozzle *J* is too small and a larger one should be used.

If the mixture on high speed is correct but to get the proper adjustment it is necessary to turn nut *B* down so that there is more than $\frac{1}{8}$ of an inch clearance between *G* and *X*, when the engine is shut down, it indicates too large an auxiliary nozzle *J* and a smaller one should be used.

To change auxiliary nozzle *J* move air horn to one side, remove plug *A-P*, insert screwdriver and unscrew *J*. Nozzles are numbered according to the drill gauge sizes; for instance, No. 59 is larger than No. 60.

Season Adjustment. — Open shutter *T* in summer, close in winter. To get best results from this carburetor warm air should be applied to the hot air horn of the carburetor from around the exhaust manifold.

Cadillac

This is an auxiliary air type carburetor with concentric float chamber. The gasoline enters the float chamber through the gasoline inlet passage passing the gasoline inlet needle valve. The air is supplied from two sources; the primary air enters at the primary air inlet passing the nozzle at the Venturi tube, the secondary air enters at the auxiliary air valve entering the mixing chamber as pure air.

A leaning device, sometimes called a "gas-saver," is provided which may be adjusted to cause a mixture in which the proportion of gasoline to air is cut down for ordinary driving speeds. The mixture is not affected by the leaning device at the closed or nearly closed position of the throttle, nor at the open or nearly open posi-

tion. The leaning device is adjusted at *G* (Fig. 53). When the adjusting screw *G* is screwed in as far as it will go the leaning device has no influence on the mixture at any throttle position.

The leaning device consists of a shutter attached to the right-hand end of the throttle shaft which covers a slot in the carburetor body when the throttle is opened slightly and then uncovers the slot when the throttle is opened wide or nearly so. A hole is drilled through the carburetor body from the mixing chamber to the slot and another hole is drilled from the float chamber to the slot. When the slot is covered by the shutter, a passage is formed from the mixing chamber to the float chamber. The partial vacuum in the mixing chamber causes a lowering of the air pressure in the float chamber resulting in less gasoline being fed through the spray nozzle. When the shutter uncovers the slot the partial vacuum in the mixing chamber has no effect on the air pressure in the float chamber and the amount of gasoline fed through the spray nozzle is not effected.

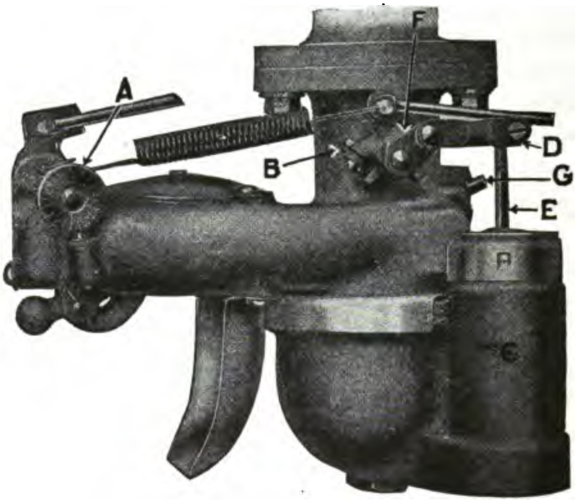
This carburetor is equipped with a device to force gasoline through the spraying nozzle when the throttle is opened quickly for acceleration and is called the "throttle pump." It is so arranged that when opening the throttle slowly it will have no effect on the mixture but when sudden acceleration is desired the plunger will be forced down suddenly as the throttle is opened. In this way the gasoline is forced out of the spray nozzle. As the throttle is closed the chamber below the plunger fills up.

The carburetor is equipped with an automatic throttle (Fig. 53) controlled by a spring. Its purpose is to prevent pulsations of air in the intake manifold from causing the auxiliary air valve to flutter when the engine is running slowly with the throttle fully opened. The automatic throttle is adjusted when the carburetor is assembled and requires no further attention.

Method of Adjustment.—Move the spark lever to the extreme left to retard the spark on the sector and the throttle lever to a position which leaves the throttle in the carburetor slightly open. Adjust the air valve screw *A* to a point which produces the highest engine speed. Turning the screw *A* in a clockwise direction increases the proportion of gasoline to air in the mixture and vice versa.

Close the throttle (move it to the extreme left on the sector) and adjust the throttle stop screw *B* to a point which causes the engine to run at a speed of about 300 R. P. M. The spark lever should be at the extreme left on the sector when this adjustment is made.

With the spark and throttle levers at the extreme left on the



Cadillac carburetor

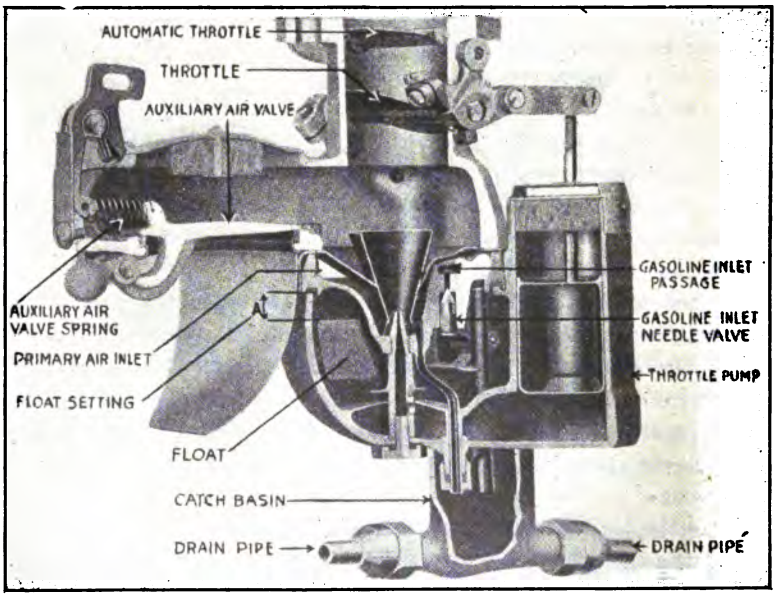


Fig. 53 — Cross-section of Cadillac carburetor

sector adjust the air valve screw *A* to a point which produces the highest engine speed. Open the throttle until the shutter attached to the right-hand end of the throttle shaft just covers the slot in the carburetor body. Then adjust the screw *G* to a point which produces the highest engine speed or to a point where the engine misses from too lean a mixture, then overcome the missing by turning the screw *G* in a clockwise direction increasing the proportion of gasoline to air in the mixture.

During very cold weather when a slightly richer mixture is desirable it may be found best to turn the adjusting screw *G* further in a clockwise direction.

Setting of Carburetor Float. — After the carburetor has been in use for sometime there may be a slight amount of wear at the point of the inlet needle and its seat. If this should occur the height of the gasoline in the carburetor bowl will rise.

To determine if the float is properly set remove the carburetor from the engine and the bowl from the carburetor. Raise the float until the inlet needle valve is just closed. The dimension *A* (Fig. 53) should then be one-half inch. The setting may be corrected by slightly bending the arm to which the float is attached.

Marvel

This is an auxiliary air type of carburetor with eccentric float chamber. The spray nozzle opening is regulated by a needle valve which constitutes the gasoline adjustment of the carburetor and it is surrounded by the Venturi tube, through which a portion of the incoming air passes at high velocity, picking up gasoline from the end of the spray nozzle.

The mixing chamber also contains the air valve and the high speed nozzle. The auxiliary air valve is held to its seat by an adjustable spring which forms the air adjustment. At a high rate of speed the suction increases. This causes the auxiliary air valve to lift from its seat admitting additional air mixed with gasoline drawn from the high speed nozzle (Fig. 54).

The air enters the carburetor through a three-way valve connected to the air regulator on the instrument board. By means of this valve the air can be taken from the heater under the exhaust manifold or directly from the atmosphere. In the " choke " position this valve partly closes the air intake causing the engine to draw excessively rich charges for starting.

The opening between the mixing chamber and the intake manifold is controlled by a butterfly valve. This is connected to the throttle

lever on the steering wheel and thus regulates the amount of mixture being fed to the engine.

The upper end of the mixing chamber and the Venturi tube are surrounded by jackets through which some of the hot exhaust gas passes to keep the carburetor warm and assist vaporization of the fuel. A damper in the jacket opening is connected to and controlled by the throttle lever so as to increase the amount of heat as the throttle is closed. In warm weather the diamond-shaped shutter on the bottom of the carburetor should be opened to allow the hot exhaust gas to escape before it overheats the nozzle.

Adjustment of the Carburetor. — Turn gasoline adjustment to the right until needle valve is completely closed. Set air adjusting screw so that end of the screw is even with the point of the ratchet

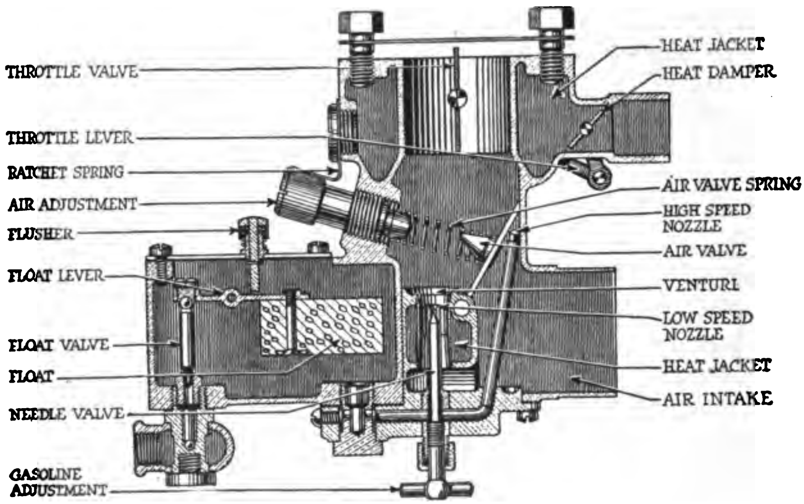


Fig. 54 — Marvel carburetor

spring just above it. Open gasoline adjustment by giving needle valve one full turn. Start engine as usual and allow it to run a few minutes with air regulator turned to "hot" until engine is thoroughly warmed up.

With the spark lever fully retarded turn gasoline adjustment to the right, closing needle valve until engine misses and then turn to left until engine idles smoothly.

Advance the spark lever and turn air adjustment screw to the left, a little at a time, until the engine misses indicating too much air and then turn it to the right until the engine runs smoothly.

To test the adjustment leave spark lever advanced and open throttle quickly. The engine should accelerate instantly. If it skips or pops back, open gasoline adjustment slightly by turning needle valve to the left. Do not touch air adjustment again unless it appears absolutely necessary. The best possible adjustment has been secured when gasoline adjustment is turned as far as possible to the right and air adjustment is turned as far as possible to the left. This allows engine to idle smoothly and accelerate quickly when throttle is opened.

Tillotson

There are many models of these carburetors, the operation being identical in all cases. The model C14A is shown in outline and

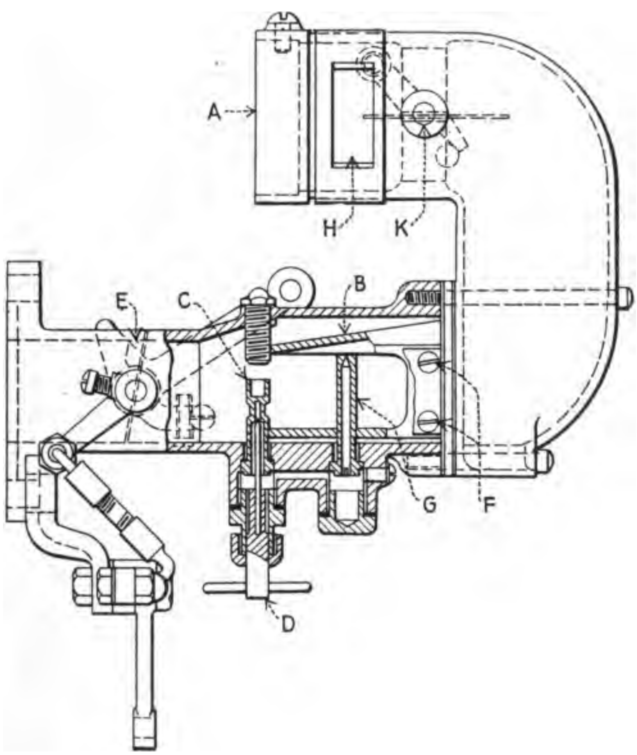


Fig. 55 — Tillotson carburetor

section (Fig. 55). This carburetor is of a very simple construction, having no auxiliary air valves and having but one control, the adjusting needle for the main jet. It is the same in principle

with the other carburetors of this construction except that provision has been made to control automatically the air volume taken into the engine at all engine speeds.

Heat, air velocity, and vacuum are the three natural elements by means of which the carburetor functions. All air is taken from a trap or stove where it is heated and conducted through a tube to the carburetor which it enters at *A*. As the air enters the mixing chamber it is restricted to a very high velocity at the end of the wedge shaped air valve *B*. At the apex of this valve is located the low speed primary nozzle *C* provided with the adjusting needle *D*. The correct opening of the small end of the air valve is predetermined to equal the low engine speed requirements and when the low engine speed fuel requirement has been found by adjusting the needle valve *D* the remaining functions of the carburetor are performed automatically.

As the throttle *E* is opened to admit a greater volume of mixture to the engine, the air valve responds through the action of two flexible reeds, which bend outwardly admitting a greater quantity of air to pass over the primary nozzle. These reeds (not shown in the illustration) are placed on the sides of the air valve, having one end fastened to the valve by screws *F*, the other end, which projects forward to the primary nozzle, being free to move. This permits the ends of the reeds to be drawn apart as the vacuum increases, enlarging the opening for the intake of air. The partial vacuum being held within the mixing chamber of the carburetor travels back through the inside of the valve and draws more heavily on the primary nozzle until this nozzle reaches its capacity of fuel delivery. At this point the secondary nozzle *G* located further back in the valve and more open to atmosphere begins to deliver the secondary supply of fuel through the effect of partial vacuum. It continues to deliver an increasing volume until the throttle has reached its maximum opening and the engine is delivering its full capacity.

By predetermining the nozzle sizes and their position with reference to their coöperative function with the air valve, the proper mixture can be maintained throughout the varying speeds of the engine.

The fuel is maintained at the proper level in the nozzles by means of the conventional float valve (not shown).

To adjust the heated air to the proper temperature, there is a slide valve *H*, which will permit a certain amount of cold air to enter and to mix with the heated air before entering the mixing chamber. In this way the proper temperature of the air can be maintained.

The choke valve *K* may be closed to facilitate starting the engine.

CHAPTER X

CARBURETORS (continued)

The carburetors explained in this chapter do not employ auxiliary air valves. The methods used to keep the proportion of air and gas constant at varying speeds is explained as each carburetor is discussed.

STEWART — MODEL 25

This carburetor is of the metering pin type, that is, it meters out the proper amount of gasoline for each speed. The action of the carburetor is as follows: The suction created in the inlet manifold draws air into the mixing chamber through air ducts, drilled holes *H,H* (Fig. 56) The same suction draws a fine spray of gasoline through the aspirating tube *L* into the mixing chamber and the air becomes impregnated with the gasoline vapor. In order that the proportion of air and gasoline vapor may be correct for all engine speeds provision is made by means of a valve *A* for the automatic admission of larger quantities of both air and gasoline vapor at high engine speed. The passages *H,H* are open at all times, but the valve *A* is held to its seat by its weight until the suction, increasing as the engine speed increases, is sufficient to lift it and admit a greater amount of air by passing around *A* at *I*. The valve *A* is joined to the tube *L* hence the latter is raised when the valve is lifted and the increase of proportionally larger quantities of gasoline is made possible. This is accomplished by means of a tapering metering pin *P* normally stationary, projecting upward into the tube *L*. The higher the tube rises the smaller is the section of the metering pin even with its opening and the greater is the quantity of gasoline which may be taken into the tube. The taper of the metering pin being carefully designed, the carburetor thus automatically produces the correct mixture and quantities for all engine speeds.

There is one adjustment which can be made on this carburetor but which should not be changed unless it is known absolutely that the adjustment is incorrect. The height of the metering pin relative to the opening of the aspirating tube can be changed. To change the fixed "running" position of the pin turn the stop screw to the right or left. Turning this screw to the right lowers the position

A — Air Valve
B — Air Valve Seat
C — Float Chamber
D — Dash Pot
E — Combining Tube
F — Metal Float
G — Gasoline Inlet Valve
H — Drilled Holes
I — Air Passage
K — Air Valve Guide
L — Aspirating Tube
M — Dash Control Pinion
N — Metering Pin Carrier and Rack
O — Mixing Chamber
P — Metering Pin
Q — Gasoline Valve Cap
S — Gasoline Passage
V — Throttle Valve Lever
Z — Filler Screen
AA — Air Inlet
CC — Filter Cap

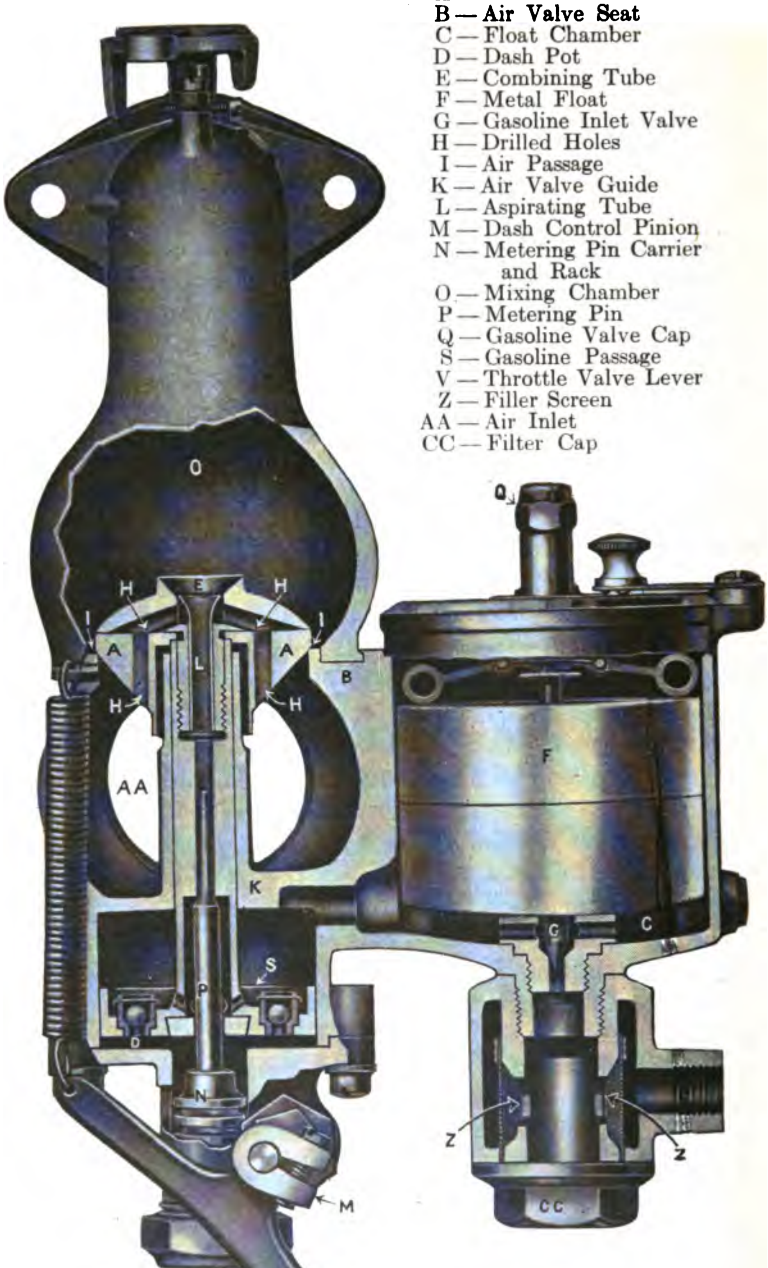


Fig. 56 — Stewart model 25

of the metering pin and turning to the left raises it. As the pin is lowered more gasoline is admitted to the aspirating tube at a given engine speed thus enriching the mixture. A wider range of adjustment of the position of the metering pin may be made by releasing the clamp *M* of the pinion shaft lever and changing its position with relation to the shaft. This requires very careful work and should only be made in extreme cases. The metering pin is also subject to control from the dash and when making any of the foregoing adjustments the dash adjustment must be all the way in.

In starting the engine, especially in cold weather, some difficulty may be experienced. To overcome this difficulty a very rich mixture is required temporarily. To obtain this without disturbing the regular carburetor adjustment a control is provided with an operating plunger on the dash or instrument board. Pulling out the plunger operates the pinion shaft at *M* on the carburetor and lowers the metering pin. This permits more gasoline to be drawn through the aspirating tube than normally. Though the quantity of air drawn into the mixing chamber remains the same a richer mixture results. A mixture of this character ignites much more readily than one having a greater proportion of air, but the resulting explosion does not produce any more power. Therefore, as soon as the engine starts the plunger at the dash should be pushed down.

In very cold weather, the dash adjustment should not be pushed all the way down after the engine starts but should be pushed part way back and left there until the engine warms up. This is necessary because the gasoline does not vaporize as readily in the cold weather.

To prime the carburetor remove Gasoline Valve Cap, *Q* and lift the float needle valve.

Hudson

This carburetor is of the metering pin type with eccentric float chamber. The gasoline enters gasoline feed regulator and passes up the *V* groove in the measuring pin. As the measuring pin is lifted it causes a larger opening supplying an increased amount of gasoline. The suction of the engine draws air through the air intake and also from the air chamber above the piston (Fig. 57). As the air is drawn from the air chamber it causes the piston to rise and lift the measuring pin. As the suction increases the greater will be the amount that the piston is raised, proportionately increasing the gasoline supply. As the piston rises a larger area for the air is provided, therefore, the velocity does not necessarily increase with the increased amount of air passing. If the amount

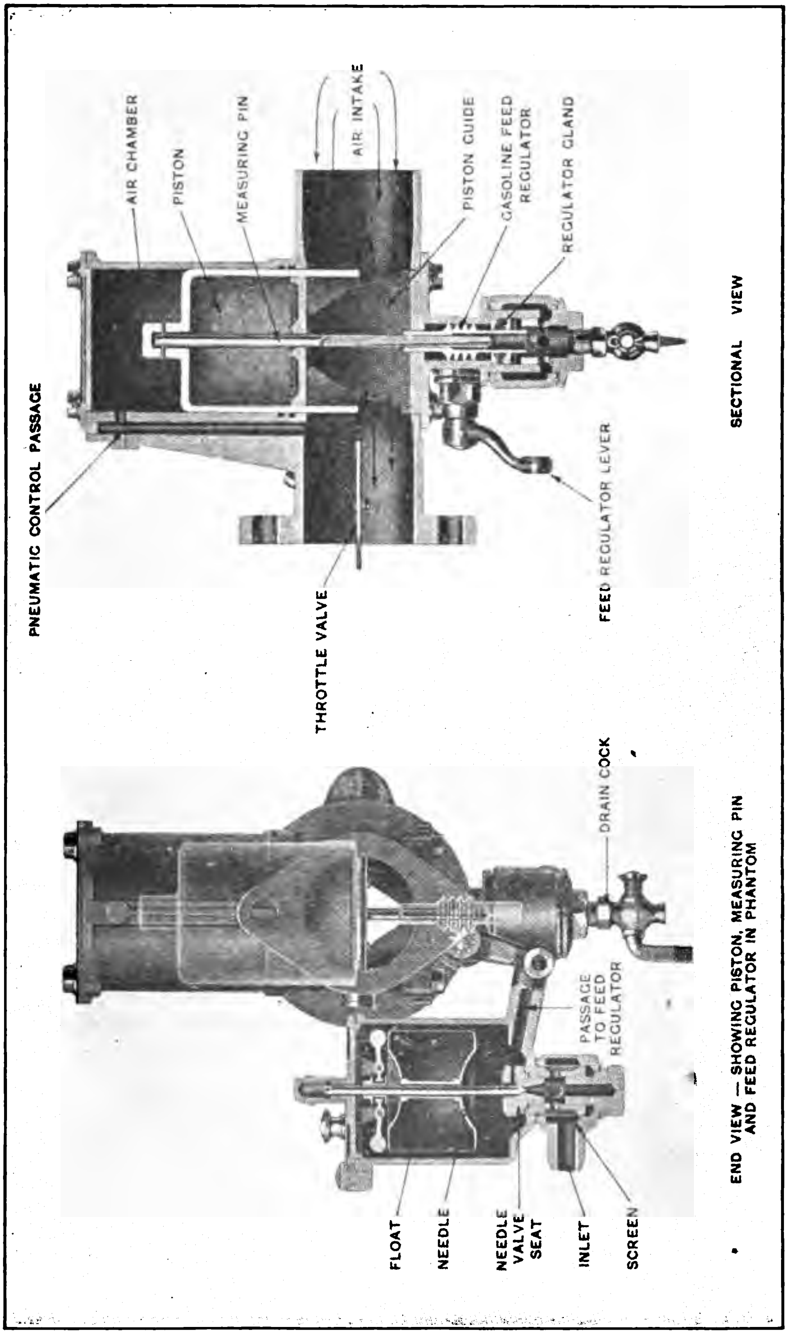


Fig. 57 — Hudson caburetor

of air passing increases and the velocity does not materially increase it will require a larger opening at the measuring pin to keep the proper proportions. This is automatically controlled by the piston at the same time.

In case the resulting mixture is not correctly proportioned the gasoline feed regulator can be adjusted. If it is lowered it will cause richer mixtures and if it is raised it will cause leaner mixtures. This adjustment is made by the feed regulator lever which is attached to a dash control.

If found necessary to enrich the mixture for starting purposes do not forget to readjust it to the lean position as soon as the engine warms up. Do not have the air control lever in the "choke" or "hot" position after the engine is warm. The increased resistance to the air intake causes a proportionately greater throttle opening than is necessary for the power developed and this results in excessive gasoline consumption.

The only attention necessary on this type of carburetor is to see that the filter under the float chamber is not clogged up, thereby restricting the flow of gasoline, and that the needle valve is seating properly and does not allow the gasoline level to increase and overflow at the regulating sleeve. It is also advisable to note the action of the carburetor to make sure that the piston valve is acting smoothly and responds to the speed of the engine. It is possible that this piston valve may stick in the cylinder through an excessive accumulation of dust which may be caused by driving on a much frequented road. Provided the strangler is used for starting it is very likely that this will not be noticed as it is possible to operate this carburetor without any valve action at all. However, if the car is used by an experienced driver who counts upon quick acceleration and good hill climbing abilities the difference will be noticed. This will be especially noticeable if driving without the strangler particularly in cold weather.

To free the valve it is only necessary to remove the cover at the top of the cylinder, withdraw the valve from its place, and clean it with a little gasoline. In putting it back a few drops of kerosene on the top of the piston will help in flushing down any sediment or grit which the gasoline may have left.

Stromberg — Model "M"

This carburetor is of a plain tube construction in which both the air and the gasoline openings are fixed in size. The gasoline is metered automatically without the aid of moving parts by the suction of air velocity past the jets (Fig. 58).

To maintain the proper proportion of gasoline and air at variable engine speeds an **air bled jet** is used (Fig. 59). The principles of

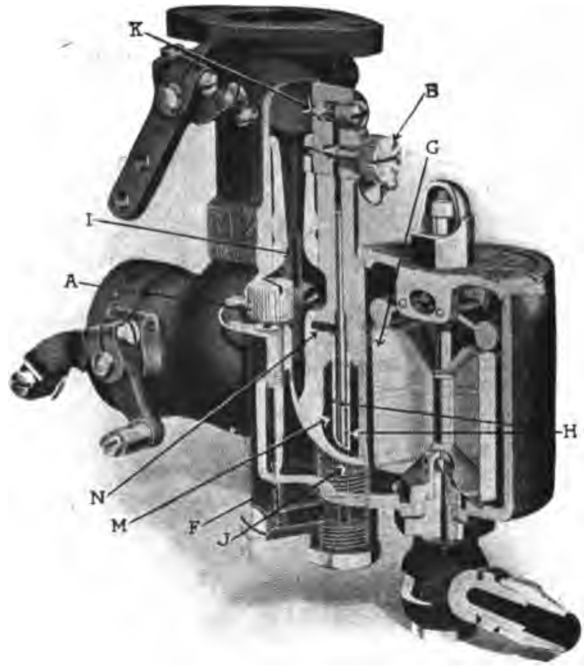


Fig. 58 — Stromberg model M

the Air Bleeder are as follows: The gasoline leaves the float chamber, passes the point of the high speed adjusting needle, and rises through the channel *B*. Air is taken in through the Air Bleeder *C* and discharged into the gasoline channel through small holes *D*. It should be noted that this air is discharged into the gasoline before the latter reaches the jet holes in the small Venturi tube *E*. As the suction of the engine increases drawing a proportionately greater amount from the holes at *E* the proportions are kept constant because of the amount of air bled with the gasoline in the channel *B*.

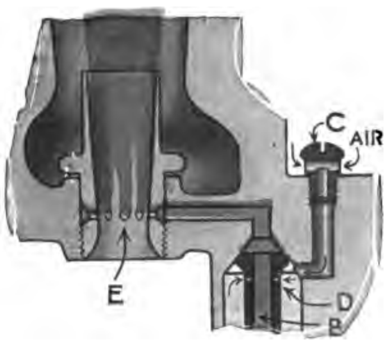


Fig. 59 — Air bleeder

The accelerating well (Fig. 60) operates as follows: The action is based upon the principle of the ordinary U-tube. If a U-tube

contains a liquid and suction is applied to one end of the tube the liquid will rise in that arm and will drop in the other arm. Referring to Fig. 60, the space *F* forms one arm of the U-tube and the space *B* the other arm. These spaces communicate with each other through the holes *G* thus forming a modified form of U-tube.

When the engine is idling or retarding in speed the accelerating well or space *F* fills with gasoline. When the throttle is opened

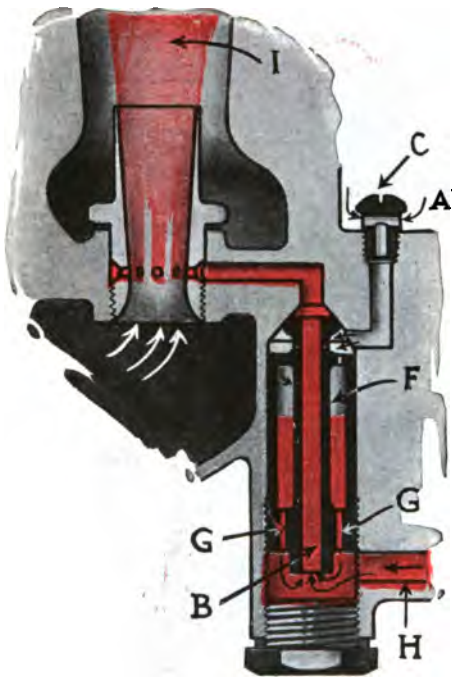


Fig. 60 — Accelerating well

increasing the suction in the Venturi tube the following takes place: Atmospheric pressure in the space *F* is exerted through the bleeder forcing the liquid down to join the regular flow from *H* passing up the space *B* and out into the high velocity air stream through the small Venturi tube. While the well acts the flow of gasoline is more than double the normal rate compensating for the lagging of the gasoline due to inertia.

Upon close observation it will be noticed that there is a series of small holes down the wall of the well. Referring to the analogy of the U-tube these holes directly connect the two arms of the U-tube. It is obvious that the smaller and fewer these holes, the faster the well will empty due to the U-tube suction, and the

larger and more of these holes, the slower the well will empty. It is therefore apparent that the rate of discharge of the well can be regulated, as required by different engines, different grades of gasoline, different altitudes, etc., by inserting wells of different drillings. The action of the well is also dependent upon the size of the hole in the bleeder because the area of the hole of the bleeder relative to the areas of the holes in the well determines the rate at which the well will empty.

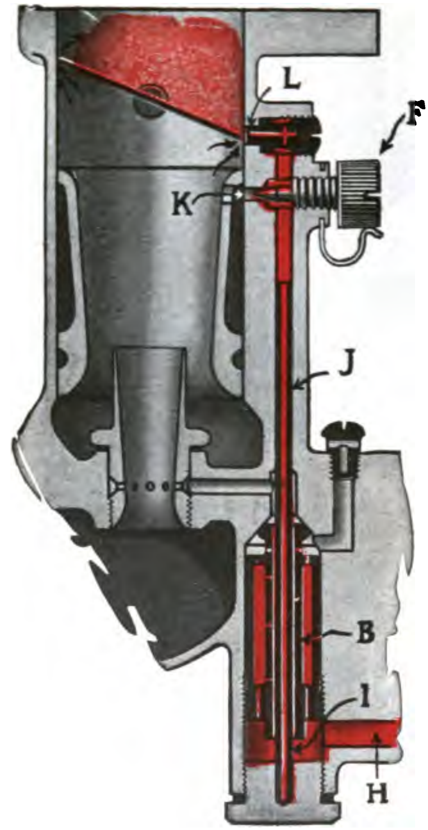


Fig. 61 — Idling jet

The operation and arrangement for idling is shown in Fig. 61. Concentric and inside of the passage *B* is located the **Idling tube** *J*. When the engine is idling, that is when the throttle is practically closed, the action which takes place is as follows: The gasoline leaves the float chamber, passes through the passage *H* into the idling tube through the hole *I*, thence up through the idling jet *L*. Air is drawn through the hole *K* and mixes with the gasoline to

form a finely divided mist which passes on to the jet *L*. This jet directs the mist of gasoline and air into the manifold just above the lip of the throttle valve. In as much as this throttle valve is practically closed, the vacuum created at the entrance of the jet *L* is very high and exceeds 8 pounds per square inch.

It is obvious, therefore, with this condition, that the gasoline will be drawn into the manifold in a highly atomized state. It is well to call attention here to the fact that the **low speed adjusting screw** *F* operates a needle valve which controls the amount of air passing through the hole *K* and it is the position of this needle valve which determines the idling mixture.

As the throttle is slightly opened from the idling position a suction is created in the throat of the small Venturi tube as well as at the idling jet. When idling, the suction is greater at the idling jet, and when the throttle is open the suction is greater at the small Venturi tube. At some intermediate position of the throttle there is a time when the suction at the idling jet is equal to that at the small Venturi tube, therefore, at this particular time the gasoline will follow both channels to the manifold. This condition (Fig. 62) lasts but a very short while because as the throttle is opened wider the suction at the small Venturi tube rapidly becomes greater than that at the idling jet. The result is that the idling tube and idling jet are thrown entirely out of action and the level of the gasoline in the idling tube drops (Fig. 63) when the throttle is wide open, in which case all of the gasoline enters the manifold through the holes in the Venturi tube. With the throttle in this position the accelerating well has emptied, and there is a direct passage for air from the Bleeder to the gasoline in the main passage, giving the "**air bled jet**" feature as explained before.

To Adjust the Carburetor. — Turn both high and low speed adjusting screws *A* and *B* completely down so that the needle valves just touch their respective seats. Then unscrew (anti-clockwise) the high speed adjustment *A* about three turns off the seat, and turn low speed adjusting screw *B* (anti-clockwise) about one and one-half turns off the seat. The air horn choke valve should be closed and the engine is set for starting. After the engine has warmed up and the air horn choke valve is wide open the carburetor is ready for adjustment.

To adjust the high speed adjustment *A* proceed as follows: Advance the spark to the position for normal running. Set the gas lever on the steering-wheel quadrant at such a position corresponding to an engine speed of approximately 750 R. P. M. Then turn down (clockwise) on the high speed screw *A* gradually, notch by

notch, until a missing of the engine results. Then turn up or open the same screw (anti-clockwise) until the engine runs at the highest

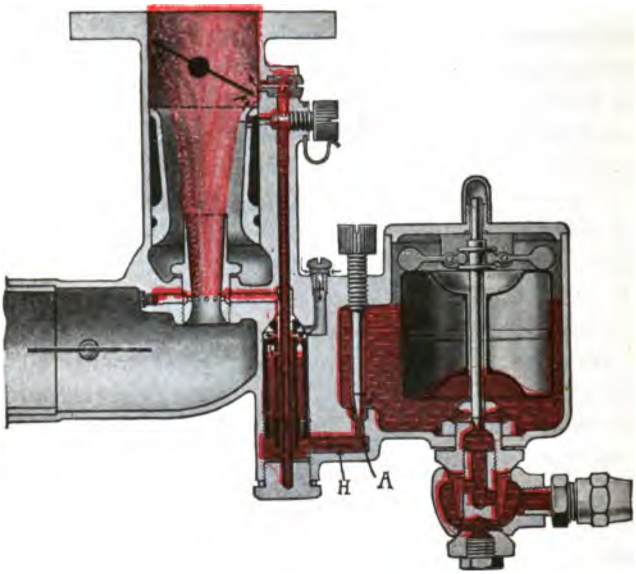


Fig. 62 — Operation at slow speed

rate of speed for that particular setting of the throttle. This gives an approximate setting of the needle *A*.

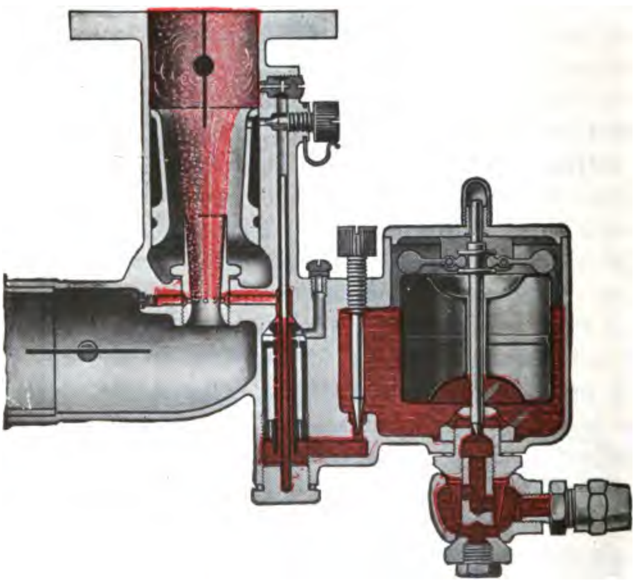


Fig. 63 — Operation at high speed

To adjust the low speed adjustment *B* proceed as follows: Retard the spark fully and close the throttle as far as possible without causing the engine to come to a stop. If upon idling the engine tends to "roll" or "load" it is an indication that the mixture is too rich and therefore the low speed adjusting screw *B* should be turned away from the seat (anti-clockwise) thereby permitting the entrance of more air into the idling mixture. This rolling of the engine might also be due to uneven compression in the cylinders, or to the lack of compression in one or more of the cylinders. The low speed adjustment is best made by carefully observing the smoothness with which the engine revolves when idling, and can be properly obtained by turning the screw *B* up or down, notch by notch, until the best idling prevails. It is safe to say that the best idling results will exist when the screw *B* is not much more or less than one and one-half turns off the seat.

After satisfactory adjustments have been made with the motor vehicle stationary it is most important and advisable to take the vehicle out on the road for further observation and finer adjustments. If upon a rather sudden opening of the throttle the engine back-fires it is an indication that the high speed mixture is too lean and in this case the adjusting screw *A* should be opened one notch at a time until the tendency to back-fire ceases. On the other hand if when running along with open throttle the engine "rolls" or "loads" it is an indication that the mixture is too rich and this is overcome by turning the high speed screw *A* down (clockwise) until this loading is eliminated.

Stromberg — Model "O"

This carburetor is of the plain tube construction similar to the type Model M, its operation in general being the same. It has several new features. Figure 64 shows the cross-section view. The double Venturi tube is employed the same as in Model M. The location of the main discharging jet and bleeder, instead of being off-set, is directly under the Venturi tube. Its operation is identical with that of the Model M.

The added features are the high speed air control, the auxiliary gasoline control, and the gasoline reducer. The high speed air control is attached to the throttle lever so that the air fed to the bleeder can be reduced at very high speeds.

The auxiliary gasoline control is designed to be operated from the dash or steering post. When the high speed needle is given a close and economical adjustment, the auxiliary gasoline control may be used for a convenient and exact adjustment for the temporarily

rich mixture needed for starting and warming up. This control may also be used as a check when the engine is firing improperly, to see if the readjustment of the fuel fed will improve the operation.

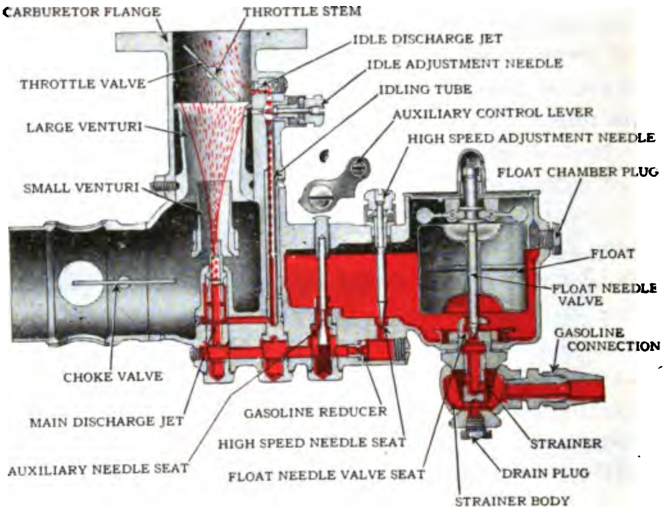


Fig. 64 — Stromberg Model O

The gasoline reducer is used at the option of the car manufacturer. Its function is to give a certain limit of adjustment to the high speed adjusting needle. If the opening at the gasoline reducer is

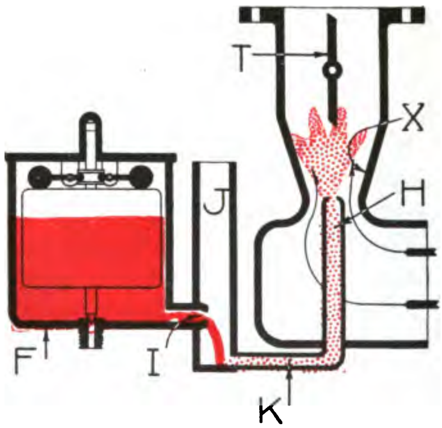


Fig. 65 — Constant flow nozzle

set, larger openings than those of the high speed adjusting needle will not effect the operation. In this way it limits the possibility of getting too great a flow of gasoline past the high speed adjusting

needle. It is, therefore, the means of limiting the high speed adjustment to a range, which will cover changes of climate and altitude, but which will not permit a harmfully over-rich adjustment.

Zenith — Model "L"

This carburetor is of the compound nozzle type and fully to understand its operation a detailed description of the principle upon which it is constructed will be given.

As was explained with a simple construction of carburetor having no regulation (Fig. 41) when the suction increases the air and gasoline increases but the proportion of gasoline increases a greater amount than the air, therefore, the mixture becomes richer.

If a jet such as shown in Fig. 65 be used in which the opening at *I* is smaller than the opening at the nozzle *H* the following condition will exist. When the car has been standing the well *J* and nozzle *H* will fill up to the level in the float chamber *F*. Although the suction is not high at ordinary speeds say 400 R. P. M. yet it could take up more gasoline from *H* than is permitted to flow through *I*. Air is also drawn up through the nozzle from the open well and the mixture is too lean for proper results.

As the speed of the car increases the suction is greater and the quantity of air increases while the gasoline remains the same because the tiny stream at *I* is independent of the suction at *H* (the suction at *H* is not transmitted to *I* because the open well *J* allows air to satisfy the suction). The mixture becomes leaner and leaner as the speed or suction increases, the action being directly opposite to that of the simple jet construction.

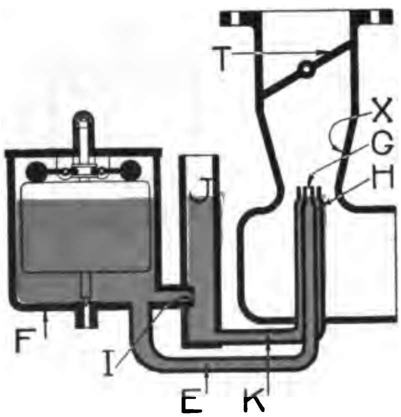


Fig. 66 — Compound jet

In Fig. 66 a construction is shown with the jets combined showing the level of the gasoline when the engine is at rest. The simple jet *G* is supplied through the pipe *E* and compounded with the jet *H* which is supplied by the pipe *K* from open well *J* and compensator *I*.

Figure 67 shows the condition when the engine is under load at 400 R. P. M. with wide open throttle. This suction is not very strong, but it is lifting gasoline from nozzle *I* and also from nozzle

H, the latter being fed from open well *J*. The action of the compensator *I* has held down the supply of gasoline and the well has emptied.

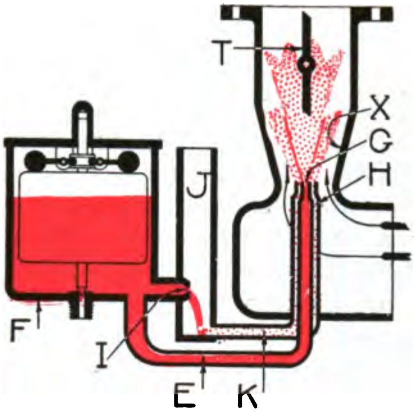


Fig. 67 — Operation at low speed

Figure 68 shows the condition with the engine turning 1600 R. P. M. The suction has greatly increased as shown by the arrows drawing more gasoline from nozzle *G*; nozzle *H* however, still gives the same measured amount because of the action of the compensator *I*.

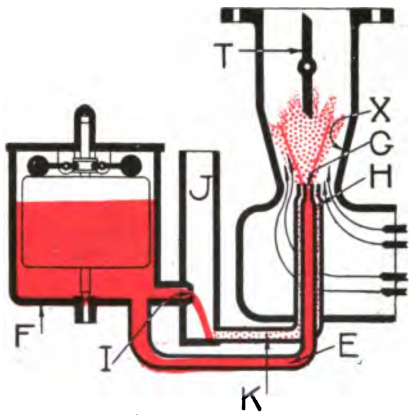


Fig. 68 — Operation at high speed

The compound nozzle receives its gasoline from two sources. At any speed both sources of supply are in action. The main jet *G* (the one controlled by suction) is selected of the proper size to give just about enough gasoline at high suction. At low suction it will, of course, be deficient. This unavoidable defect of one nozzle, starting poor and growing richer until it is almost right at high

suction, is compensated for by the peculiarity of the other jet *H* which also starts poor and keeps growing poorer. The compensator *I* supports the main nozzle *G* at low suction when it is most needed. One supplements the other so that at every engine speed there is a constant ratio of air and gasoline to stimulate efficient combustion.

Idling Device. — At low speed when the butterfly throttle valve *T* is nearly closed the main jet and cap jet gives but little or no gasoline, but as there is considerable suction on the edge of the butterfly, the gasoline is drawn through the idling device. This device (Fig. 69) consists of the idling tube *J* within the secondary well *P* inserted in the first well at the bottom of which the compensator *I* is located and which is open to atmospheric pressure through holes *A*.

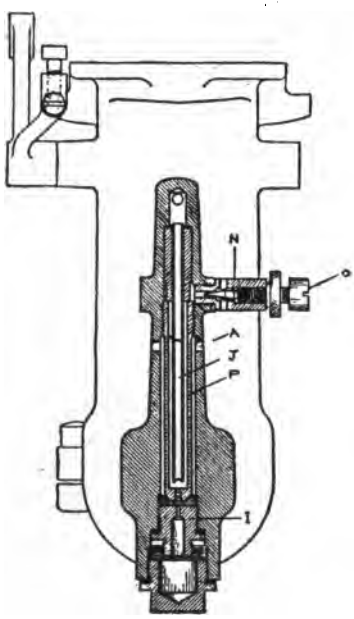


Fig. 69 — Idling device

Gasoline from the compensator *I* flows through the calibrated hole in the bottom of the secondary well *P* which in turn is adjustably open to the air through the idling screw *O*. The idling tube *J* leads to a hole located at the edge of the butterfly throttle valve where the suction is most strongly felt. This suction lifts the gasoline through the idling tube and, in combination with the air passing the butterfly valve, forms the idling mixture.

There are four adjustments which are possible with this type of carburetor.

1. Choke tube *X*.
2. Main jet *G*.
3. Compensator *I*.
4. Regulator screw *O*.

Choke Tube too Large. — The " pick up " will be defective and cannot be bettered by the use of a larger compensator. Slow speed running will not be very smooth. The engine will have a tendency to " load up " under a hard pull and at high speed the exhaust will be of an irregular nature. This " loading-up " will be much worse if the manifold is too cold.

Choke Tube too Small. — The effect of a small choke tube is to prevent the engine from taking a full charge with the throttle opened wide. The " pickup " will be very good but it will not be possible to get all the speed of which the car is capable. Remember that when the choke (Venturi tube) is increased more air is admitted and the mixture is correspondingly thinned. The influence of the main jet is mostly felt at high speed.

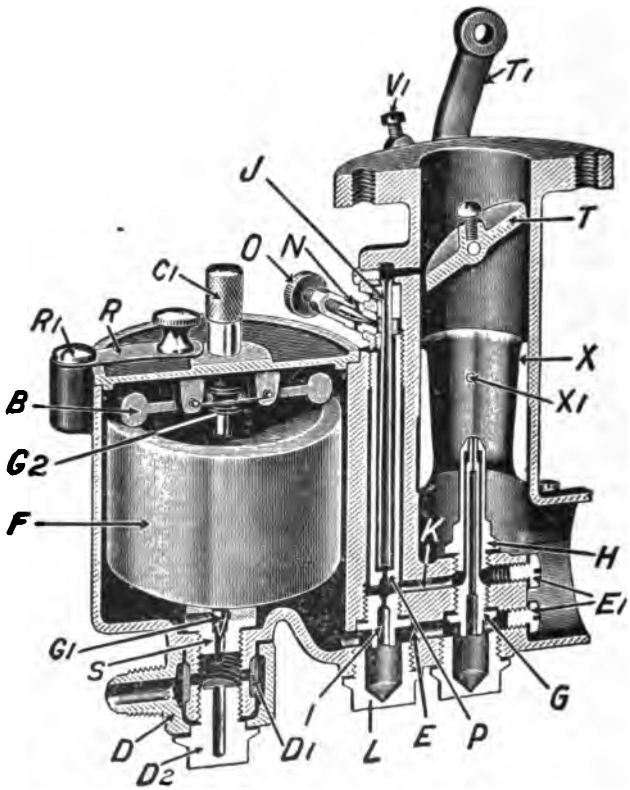


Fig. 70 — Zenith model L

Main Jet too Large. — At high speed on a level road it will give the usual indications of a rich mixture; irregular running, characteristic smell from the exhaust, firing in the muffler, sooting up at the spark plugs, and low mileage.

Main Jet too Small. — The mixture will be too lean at high speed and the car will not attain its maximum speed. There may be back-firing at high speed, but this is not probable especially if the choke and main jet are according to the factory setting. This back-firing is more often due to large air leaks in the intake or valves or to defects in the gasoline line.

The compensator size is best tried out on a long gradual hill of such a slope that the engine will labor rather hard to make it on high gear. A long, even, hard pull of this sort taxes the efficiency of the compensator to the utmost and will indicate readily the correctness of its size.

Compensator too Large. — This will cause too rich a mixture on a hard pull. It will give the same indication as for rich mixture at high speed on the level.

Compensator too Small. — This will cause too lean a mixture making the engine liable to miss and give jerky action of the car on a hard pull.

Idling Device too Small. — It will be impossible to obtain a satisfactory mixture except by turning the idling (adjusting) screw all the way in. In this event put in a larger idling device.

Idling Device too Large. — It will be impossible to obtain a satisfactory mixture unless the idling screw is turned out as far as possible. In this case put in a smaller idling device.

It has been found from practice that it is rarely necessary to make adjustments on this carburetor as the conditions are carefully calculated when installing the carburetor by the engine manufacturer, however, in a few cases where the climatic conditions or the grade of gasoline vary greatly from the ordinary standards, the compensator *I* and the jet *G* may have to be changed.

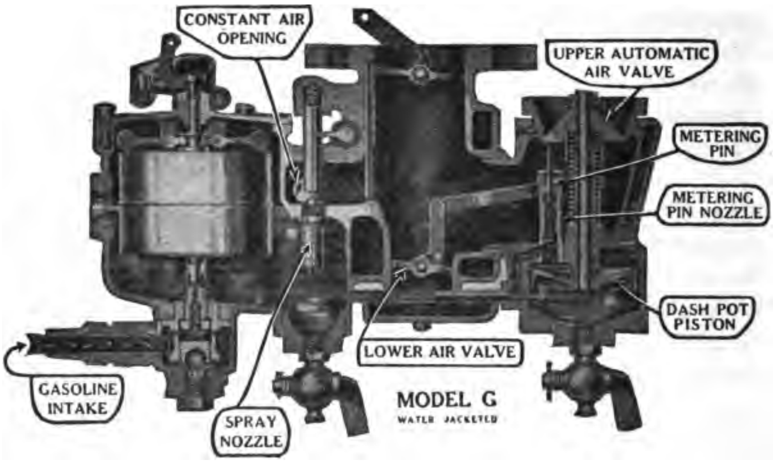
Rayfield

The Rayfield carburetors are made in two types, models G and L. The difference is that model G is water-jacketed (Fig. 71). These carburetors are of the mixed type, having both auxiliary air valves and metering pins. The gasoline supply enters through the gasoline intake passing the needle valve which is operated by the float. Gasoline is supplied from the float chamber to the two nozzles, marked in Fig. 71 as "spray nozzle" and "metering pin nozzle."

Air enters the mixing chamber from three sources: Through a constant air opening which is a hole in the side of the carburetor so that the air in entering the mixing chamber passes the spray nozzle. Air also enters through the upper automatic air valve, this air passing the metering pin nozzle. The lower air valve admits air directly to the mixing chamber and is operated by levers which are controlled by the automatic air valve.

The operation of this carburetor is as follows: With a closed throttle and the engine idling, air enters through the constant air opening picking up gasoline at the spray nozzle. As the speed is

increased and the throttle opened wide, the increased suction will cause the automatic air valve to open. This valve in opening causes the lower air valve to open and at the same time forces down the metering pin which increases the opening at the metering pin nozzle,



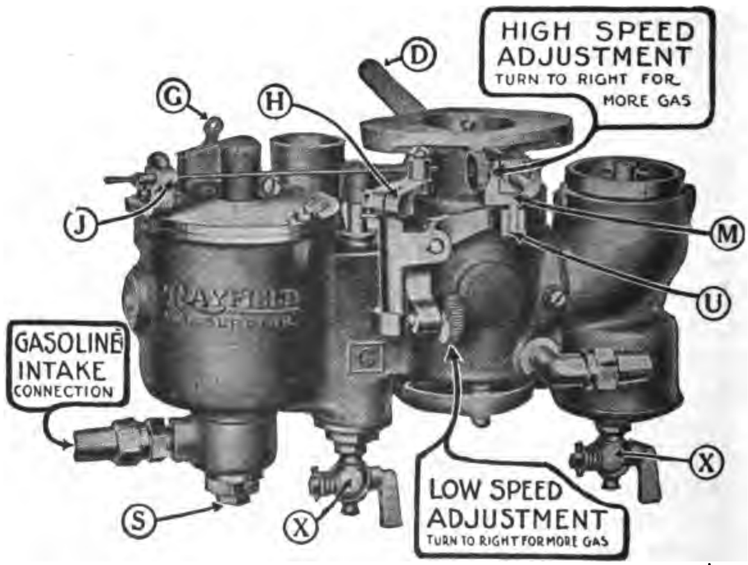


Fig. 71 — Rayfield carburetor

causing a greater amount of gasoline to be supplied. When suddenly acclerating the operation is as follows: The automatic air valve opening suddenly causes the dash-pot piston to force gasoline out

of the metering pin nozzle, thus enriching the mixture which will compensate for the lag of the gasoline due to inertia.

Adjusting Low Speed. — With throttle closed, dash control down, close nozzle needle by turning low speed adjustment to the left until block *U* slightly leaves contact with cam *M*. Then turn to the right about three complete turns. Start engine and allow it to run until warmed up. Then with retarded spark close throttle until engine runs slowly. With the engine thoroughly warm make final low speed adjustment by turning low speed screw to the left until engine misses and then turn to the right a notch at a time until engine idles smoothly. If the engine does not throttle low enough turn stop arm screw *A* to the left until the engine runs at the lowest number of revolutions desired.

Adjusting High Speed. — Advance spark about one quarter. Open throttle rather quickly. Should engine miss, it indicates a lean mixture. Correct this by turning high speed adjustment screw to the right one notch at a time until the throttle can be opened quickly without the engine missing. If "loading" or "choking" is experienced when running under heavy load with throttle wide open, it indicates too rich a mixture. This can be overcome by turning high speed adjustment to the left.

To Start Engine When Cold. — First, close throttle and pull dash control all way up. Second, when engine starts open throttle slightly and push dash control ¼ way down. Third, as engine warms up push control down gradually as required. When thoroughly warm push dash control all way down. When engine is warm it is necessary to pull dash control only part way up for starting.

Schebler — Model A, Special

This carburetor is of the plain tube type with eccentric float chamber. All the air enters at *I* and passes through the Venturi tube past the nozzle to the inlet manifold (Fig 72). The gasoline supply enters at *12* passing through the screw *11* and enters the float chamber. The proper level is maintained in the usual manner by a float *15* operating a needle valve *13*. From the float chamber the gasoline has two paths; one is past the idle adjusting needle valve *9* to passage *7*, the other is past main fuel adjusting needle valve *14*.

When starting, the choke should be closed (Fig. 73), especially in cold weather and the throttle *19* nearly closed. This shuts off the air supply and the suction causes gasoline to be drawn through passage *7* and out of the opening just above the throttle. Some

gasoline will also be drawn from the three holes *21* and the lip *6*. This gives a rich mixture which makes starting easy.

When running idle the throttle is closed. This only permits a small amount of air to pass through the Venturi tube, its velocity

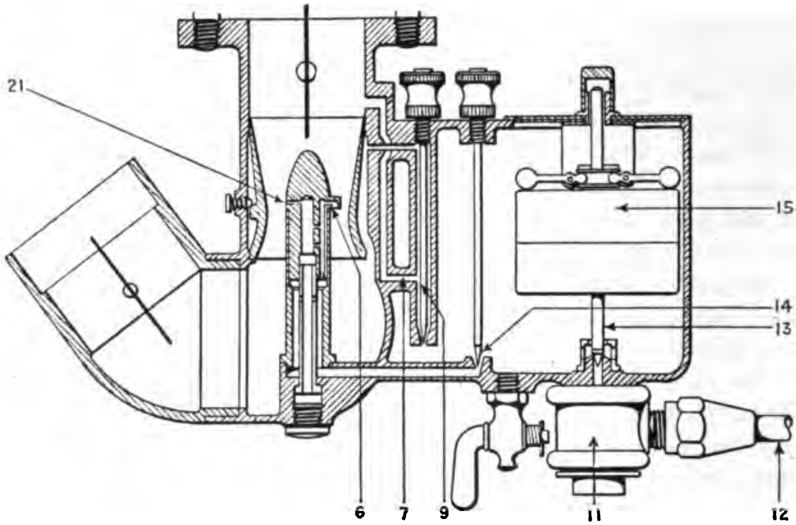


Fig. 72—Schebler Model A Special Carburetor

not being sufficient to draw gasoline from the main jet. The greatly restricted area at the throttle creates a suction at the opening of passage *7*. Some of the air entering will pass under the edge of

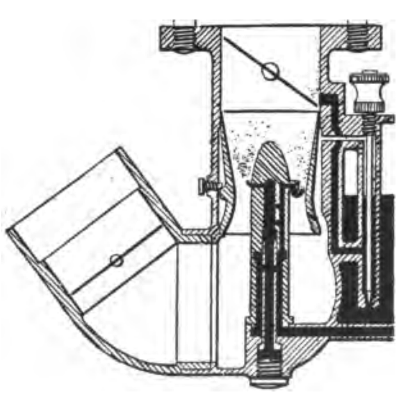


Fig. 73—Operation choked

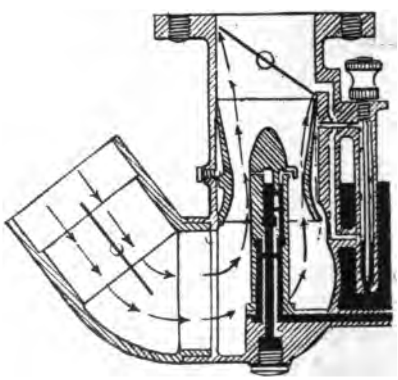


Fig. 74—Operation running idle

the Venturi tube (Fig. 74) into passage *18*, thence through passage *7* mixing with the gasoline. This mixture is delivered through the opening just above the throttle.

As the throttle is opened the amount of mixture drawn through the Venturi tube is increased. The velocity of the air now being sufficient to cause a suction which will draw fuel through the three holes *21* (Fig. 75). The incoming air strikes the projecting lip on the nozzle housing and due to its velocity enters the hole *6*. Due to the U-tube construction contained in the nozzle housing, the level of gasoline in the arm connected to the opening *6* will be lowered uncovering holes between this arm and arm *20*. As these holes are uncovered the air passes through them mixing with gasoline in passage *20*. Instead of pure gasoline being delivered at holes *21*, a spray of air and gasoline is delivered which mixes with the air being drawn through the Venturi tube. Some mixture may be delivered by the idling jet, decreasing as the throttle is opened.

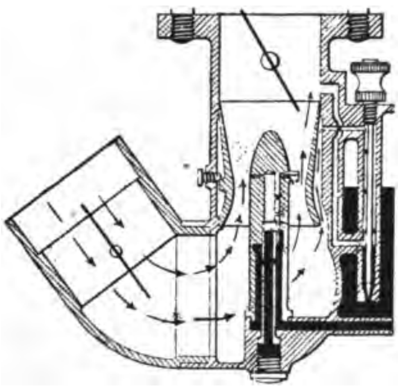


Fig. 75 — Operation under partial load

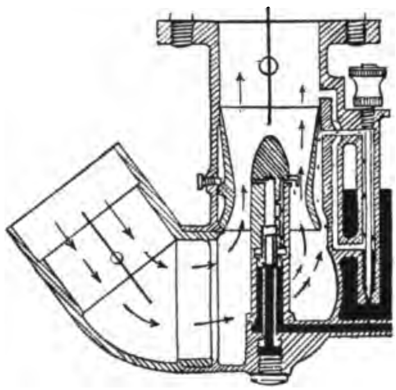


Fig. 76 — Operation under full load

When the throttle is wide open (Fig. 76) the increased amount of air passing through the Venturi tube causes a much greater suction at the holes *21*, likewise the pressure at the hole *6* is increased causing the level to be lowered still further in the U-tube. This permits more air to be drawn through the communicating holes mixing with the gasoline in the passage *20*. Thus the proportion of air and gasoline delivered to the mixing chamber is kept constant as an increasing amount is drawn through the holes *21*. If only pure gasoline was drawn the mixture would become richer but as both air and gasoline are drawn from the holes *21*, this air bleeding keeps the mixture constant at all speeds.

Adjustment. — There are but two adjustments on this carburetor both of which control the amount of gasoline supplied. The idle adjusting needle valve *9* regulates the supply of gasoline for idling and the main needle valve *14* regulates the amount of gasoline supplied to the main fuel nozzle *4*.

Screw out both adjusting needles several turns. Start the engine with the throttle slightly open. Slowly turn the idle adjusting head *17* to the right or towards the " less gas " position as indicated by the dial until the engine runs smoothly. Adjust the engine speed for running idle by means of the throttle lever stop screw on the throttle lever. Open the throttle wide allowing the governor to regulate the engine speed and with a retarded spark turn the main gas adjusting head *16* toward the " less gas " direction until the engine begins to miss or back-fire. Turn the adjusting head in the " more gas " direction just sufficiently to stop the engine missing or back-firing. These adjustments should produce a good mixture.

For starting or warming up with the present day fuel it is almost always necessary to use the air choke until the proper operating temperature is obtained. The engine will start readily with the choke closed one half to three quarters of the way. When the weather is very cold it may be necessary to close the choke entirely, but this should be done only for an instant, as it cuts off all the air and delivers practically raw gasoline.

White

The White is an eccentric float, multi-jet type of carburetor (Fig. 77). Air enters at opening *47*, which is provided with a choke *42*. The gasoline flows from the float chamber to the low speed nozzle *29* and high speed nozzle *28*. A small drilled hole *62* in the side of low speed noozle *29* near its base supplies gasoline to a passage leading to a vertical well *64* in the side of the carburetor body.

The nozzles are incased in nozzle sheaths *34* and *33*. Low speed nozzle sheath *34* is open at the top but closed at the bottom to air entering at *47*. High speed nozzle sheath *33* is open at the top and drilled with holes *63* at the bottom permitting some of the air to be drawn up inside the sheath discharging at its top. The starting nozzle *65* dips into the vertical well *64* and supplies gasoline through a small drilled hole just above the throttle valve. Screened hole *106* opening into the top of the well, maintains atmospheric pressure at all times. The throttle valve *2* is of the barrel type, consisting of a metal cylinder with twin openings cut through it of the proper shape to admit mixture. As the throttle is revolved on its axis the opening from the low speed nozzle is gradually uncovered. At a certain point the opening to the high speed nozzle is uncovered and at wide open throttle position, both passages are completely un-

covered. A screw *36* is provided regulating the amount of air supplied with the throttle closed and the engine idling.

Referring to the diagrams in Fig. 78 the operation of the carburetor is as follows:

For idling or starting the throttle is completely closed (Fig. 78A). Suction in the intake manifold causes a reduction in pressure above the throttle *T*. Atmospheric pressure exerted at the top of well *W* causes gasoline to rise in the starting nozzle *N*. At the same time,

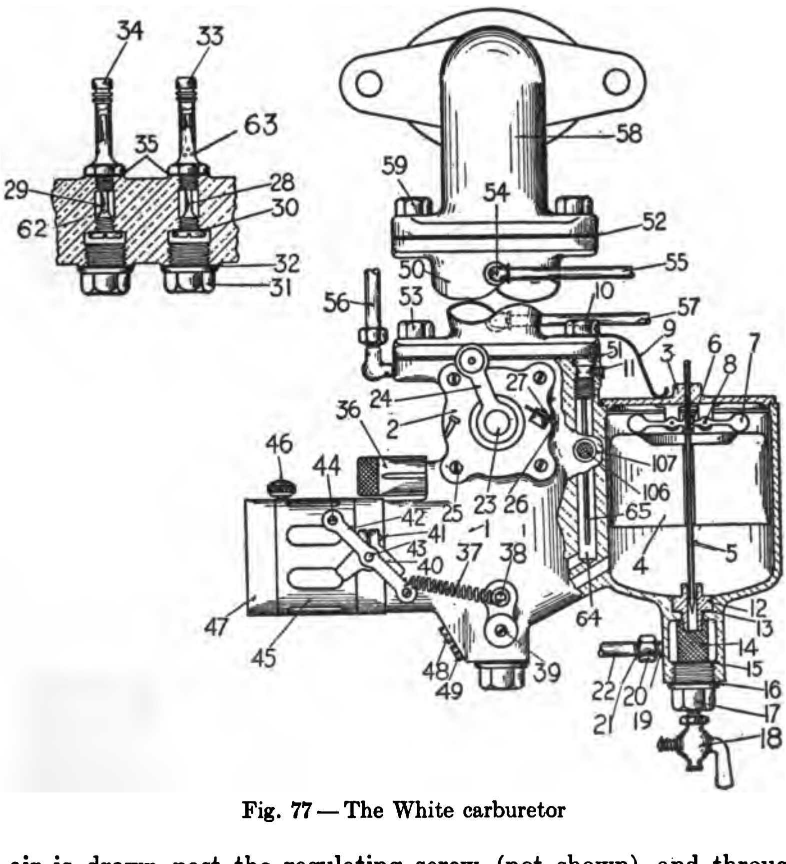
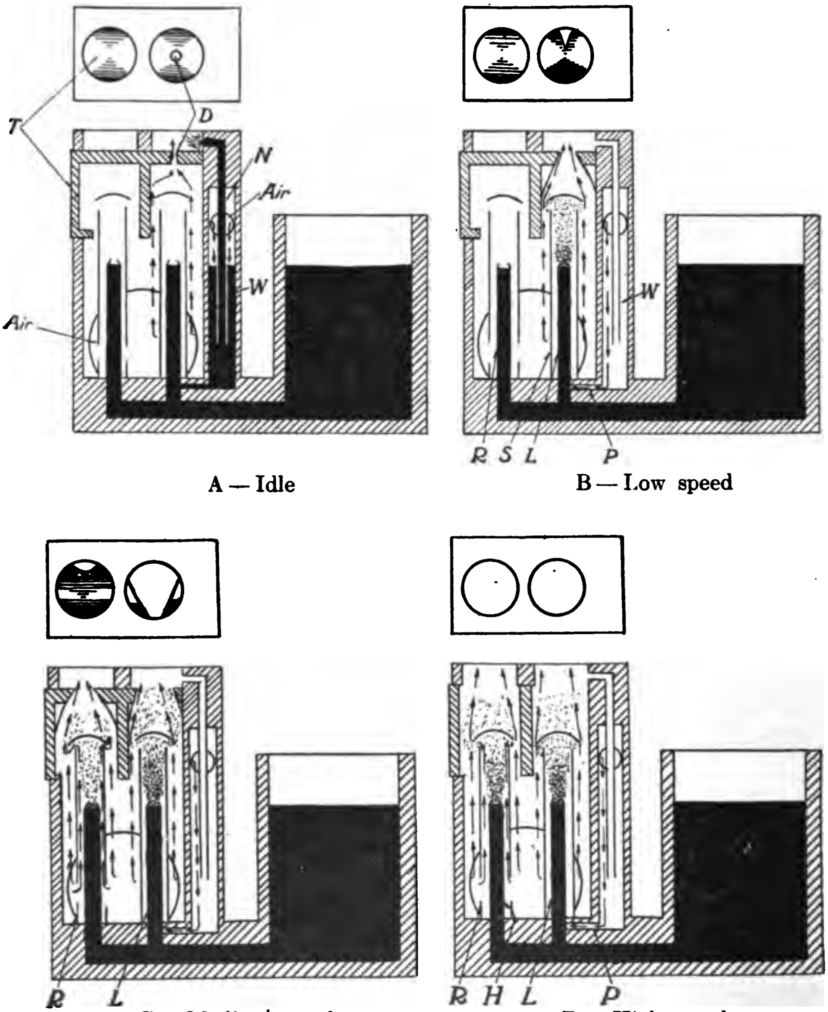


Fig. 77 — The White carburetor

air is drawn past the regulating screw (not shown) and through the drilled hole *D* producing a mixture for starting and idling. The choke must be closed when starting, reducing to a minimum the amount of air drawn through *D*.

For low speed the throttle is turned so that the low speed passage is partially uncovered (Fig. 78B). A considerable volume of air is drawn past the low speed nozzle sheath *S* causing low speed nozzle *L* to deliver gasoline which passes out the opening at the top of the

sheath and mixes with the incoming air. The well *W* is almost immediately emptied, a small quantity of air probably being drawn in through the passage *P*. The high speed nozzle *H* is still completely covered.



A — Idle

B — Low speed

C — Medium speed

D — High speed

Fig. 78 — Operation of White Carburetor

As the throttle is turned to the medium speed position, the low speed passage is further uncovered and the high speed passage is uncovered slightly (Fig. 78C). The low speed nozzle *L* functions as before, the increased suction causing it to deliver more mixture. Additional air and gasoline is supplied through the partially un-

covered high speed passage, air passing in at the bottom of the sheath *R*.

As the throttle is turned to the high speed position, both low and high speed passages are completely uncovered, bringing both nozzles fully into action (Fig. 78D). The maximum volume of air is drawn through both the low and high speed openings. Low speed nozzle *L* draws as much air as possible through passage *P* and high speed nozzle *H* delivers its maximum. It is probable that the air passing through the sheath *R* increases the suction on high speed nozzle *H*. If the throttle is suddenly opened wide a large volume of air will rush in past *R* before a flow of gasoline from *H* is established. This will cause the engine to " die."

Adjustment. — The only adjustment on this carburetor is made by the idle adjusting screw *36* with the engine running and the car standing still. If there is too much air, this screw should be turned to the right or in. If there is not enough air, it should be turned to the left or out. Further regulation of the quantity of air and gasoline for every position of the throttle valve is automatic. Too rich a mixture may be caused by dirt in the air inlet screens. These should be kept clean.

In extreme cases, the nozzles *34* and *33* may be replaced by others of different drillings. Both the hole at the top of low speed nozzle *34* and hole *62* in its side near the base vary in size. The high speed nozzle *33* is seldom changed.

The air coming in at *47* is supplied through a tube running to a stove on the exhaust pipe. A shutter *45* is provided to regulate the temperature of this air. This shutter should be closed in winter and open in summer. Additional heat is supplied by pumping warm water through the jacket on the inlet manifold *50*.

Peerless Eight

This carburetor is of the auxiliary air type with eccentric float chamber (Fig. 79). The gasoline enters the float chamber at *1* and operates the needle valve *2* and cuts off further supply of gasoline until the level falls. From the float chamber the gasoline passes direct to the nozzles *3* and *4*, which supply gasoline to the mixing chamber.

Air enters the auxiliary chamber from three sources: through the Venturi tube *5*, passing nozzle *3*; through the passage *A*, passing the nozzle *4*; through the auxiliary air valve *6* as pure air.

When idling the air enters and passes through the Venturi tube *5*, picking gasoline from the primary nozzle *3*.

As the throttle is further opened additional air must be had above the primary nozzle to give the proper mixture. This air is obtained through the auxiliary air valve *7*, which opens and permits pure air to enter to mix with the mixture from the primary passage and nozzle. The action of the valve is to open sufficiently to keep the mixture at the proper proportions, the spring *8* governing the amount that the valve will open.

At high speeds valve *9* is opened and permits air to enter passing nozzle *4* and supplies the additional mixture necessary for these speeds. Valve *9* is operated mechanically by a lever attached to the throttle valve.

For quick acceleration when the throttle is opened suddenly the plunger *10* is provided which gives the additional gasoline necessary to overcome the possibility of too lean a mixture.

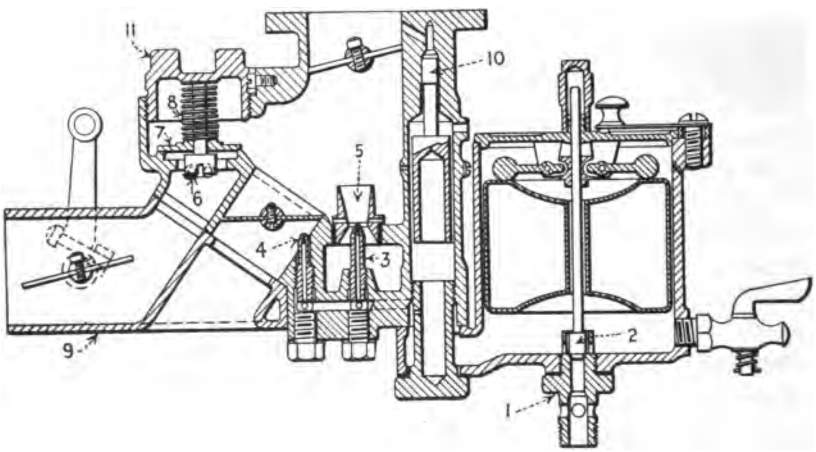


Fig. 79 — Peerless eight carburetor

Adjustment. — The adjustment of this carburetor is by air valve *7*, by turning nut *11*. If the engine is warmed up and running at approximately 500 R. P. M. disconnect the wires from the spark plugs of one block of cylinders and adjust nut *11* until the engine idles properly. This being done adjust valve in the same manner for the other set of cylinders. Connect all wires to their respective spark plugs and reduce the speed of the engine as much as possible. The valves may need a slight adjustment owing to all eight cylinders now turning the flywheel.

In the summer or in high altitudes, it may be necessary to use smaller supply holes in the compensators, which enter sides of car-

buretor and supply nozzles. Normally No. 66 drill will be used on the primary nozzles, but No. 68 or No. 70 may be required for extreme economy. Whereas the supply hole for the secondary nozzle will be No. 56 drill, but this may be No. 58 or No. 60 for higher altitudes.

Miller Model H

This carburetor is of the multiple jet type and has no other adjustment than the changing of the jet tubes to meet the necessary requirements of the engine. These jet tubes are set in a row (Fig. 80) and as the barrel throttle above them is rotated or opened, they go into action one after another as they are uncovered. The size of the Venturi or main air passage is increased by the same rotation of the throttle.

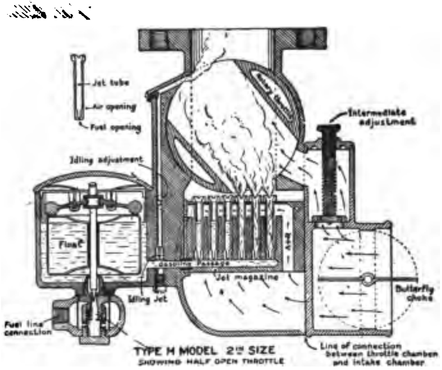


Fig. 80 — Miller carburetor

The jet tubes are opened at the top end and closed at the bottom, except for the hole which is the fuel jet. Around the lower end of the tubes threads are cut, and just above these threads are four small holes drilled through the tube. The tube guides, in the magazine above the threads, are larger than the tubes, which give a space or air jacket that surrounds each tube. These spaces connect directly with the outside air. When not in operation the tubes fill with fuel to the height of the float level.

To change the adjustment of this carburetor, it is necessary to change the jet tubes, and this should be done by one very familiar with the operation of this carburetor.

The New Holley

This carburetor is of the plain type construction. The air and gasoline openings are fixed in size. The gasoline is metered automatically without the aid of the moving parts, by the suction of air velocity past the jets. At the base of the float chamber is a strainer through which all the gasoline entering the carburetor must pass. This eliminates the possibility of dirt getting into the

carburetor to effect the operation of same. This strainer is easily removed by unscrewing the nut to which it is attached (Fig. 81).

The operation of the carburetor is as follows: When the engine has not been operating the gasoline is at the level shown in Fig. 82,

Fig. 81 — Holley carburetor

that is, jets J and G are filled with gasoline, also passageway L, and the accelerating and idling wells H and F.

In the idle position (Fig. 83) the fuel is taken into the low speed tube G, through the hole R, through the horizontal passage V and so up the vertical tube H, receiving a small accession of air at hole E and a larger quantity at the port P-$_1$; both air and fuel being discharged at the port P-$_2$, which is controlled by the low speed adjusting needle O. The fuel is thoroughly broken up by the air flowing at a high velocity past the lower edge of the throttle D under the influence of the full engine suction.

On opening the throttle slightly the lower port P-$_1$ ceases to serve as a vent to the port P-$_2$ and delivers fuel and air simultaneously with the port P-$_2$ (Fig. 84). The increased quantity of

air thereby drawn up the tube *H* increases the flow of air down through the tube *G* and also increases the flow of fuel through the hole *R*.

The increased flow of air down the tube *G* increases the local depression in the throat of the Venturi *B*, thereby maintaining the level of the fuel at, or near, the top of the nozzle *J*.

During the normal running at high speed, air flows down the annular well *F* and mixes with the fuel flowing in the horizontal

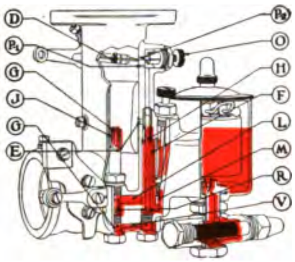


Fig. 82 — Still motor position

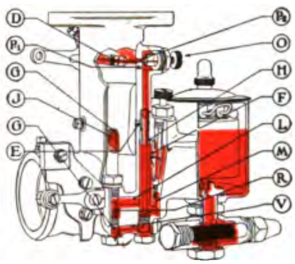


Fig. 83 — Idling position

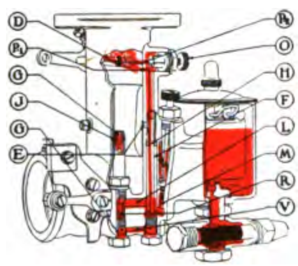


Fig. 84 — 20 M. P. H. position

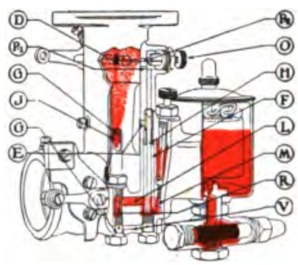


Fig. 85 — Wide open position

passage *L* from the restriction *M* and the mixed air and fuel issues from the nozzle *J* (Fig. 85).

On closing the throttle suddenly the flow of fuel up the nozzle *J* is checked, but the fuel in this nozzle flows into the passage *G* through the orifice *R* and the low speed operation is resumed as described above without any missed explosions.

Adjustments. — Before any adjustments are attempted the engine must be warm — moto-meter should show 100° to 150° — a cold engine retards vaporization of fuel.

There are two main adjustments; namely, the main needle valve, which regulates the amount of fuel consumed when the throttle is wide open, and in a less degree the idling fuel; and the idling needle valve, which finely regulates the amount of fuel consumed when the engine is idling (throttle in closed position).

To adjust the main needle valve, open the hand throttle slightly, so that the engine runs at a speed corresponding to approximately 15 miles an hour on the road. Turn this needle clockwise, which reduces the amount of fuel, until the engine back-fires through the carburetor, and then turn the needle counterclockwise, which increases the amount of fuel, until the engine runs smoothly and ceases to back-fire. The correct setting of the main needle is from 1½ to 2 turns off the seat.

The idling needle is adjusted in the same direction as the main needle, that is, to increase the amount of fuel, turn the needle counterclockwise, and to decrease the amount of fuel, turn the needle clockwise. The idling needle should be opened (turn counterclockwise) until the engine does not roll." If, after having done this, the idling speed is too fast, the lock screw should be loosened, and then the set screw should be turned counterclockwise until the desired speed is obtained, when the lock screw should be tightened. After making the latter adjustment, if the engine tends to roll, the idling needle should be turned slightly counterclockwise.

In starting a cold engine it is usually necessary to "choke" or "strangle" the carburetor temporarily, that is, to increase the amount of gasoline and decrease the amount of air going through the carburetor to the engine. The "strangler" throttle or "choke" is controlled by a button or lever on the instrument board. When the engine starts to warm up the strangler should be gradually opened until it is wide open, in which position it should be left. The slot in the strangler throttle shaft should be in this position (—) when the dash control indicates that the valve is wide open.

The carburetor flange should be tightly fitted, by means of a good gasket, to the engine so that there are no leaks. The functioning of the carburetor and its adjustments will be interfered with if air is leaking.

CHAPTER XI

PUDDLE TYPE CARBURETORS

The carburetors explained in the preceding chapters are of the sprayer type, that is, a nozzle is used to supply the gasoline to the mixing chamber in the form of a spray. There are certain types of carburetors which do not use a nozzle but allow the incoming air to pass over the surface of a puddle of gasoline and draw off vapor carrying it to the mixing chamber. For this reason they are called the puddle type of carburetor. The most common of these types will be explained in this chapter.

Kingston — Model "Y"

This carburetor was used on Ford Cars and is of the puddle type. The gasoline enters the float chamber passing the gasoline supply valve until the proper level is attained. The gasoline from the float chamber passes the valve and fills the recess directly around it (Fig. 89).

The mixing chamber is of a peculiar form, so designed that all the primary air must pass over the small pool of gasoline at the bottom of the mixing chamber before it reaches the engine. The amount of gasoline supplied to the mixture may be varied by regulating the needle valve.

At low speed all the air entering passes through the main air inlet (primary air) and picks up the gasoline carrying it to the cylinders. As the speed increases this mixture becomes richer and additional air must be supplied which does not pass over the puddle of gasoline. The additional air is admitted through the auxiliary air duct passing the auxiliary air valves of the ball type and entering the inlet manifold. These balls are so arranged that as the suction increases they lift in turn from their seats admitting a greater amount of air.

The only adjustment on this carburetor is the needle valve which when turned to the right causes the mixture to become leaner and when turned to the left causes richer mixtures.

Holley — Model "S"

This carburetor is of the puddle type with concentric float. (Fig. 90). The gasoline enters the gasoline inlet pipe (Fig. 91)

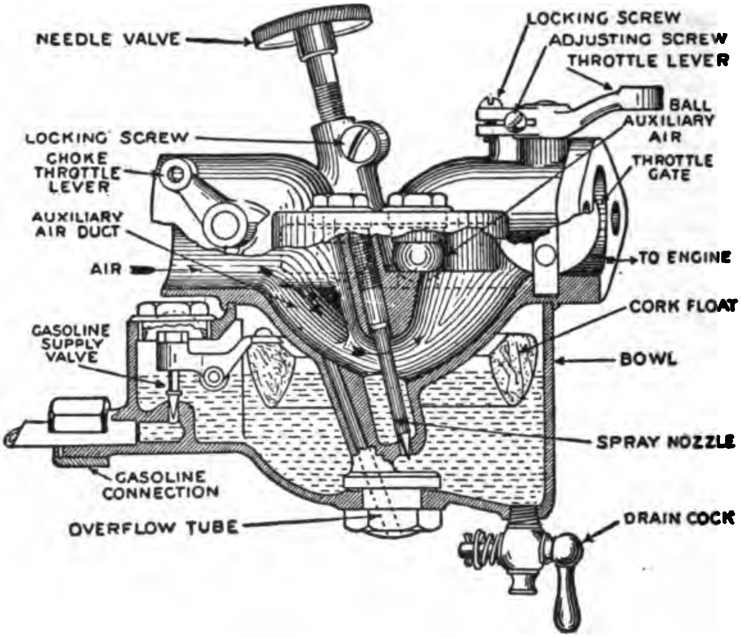


Fig. 89 — Kingston model Y

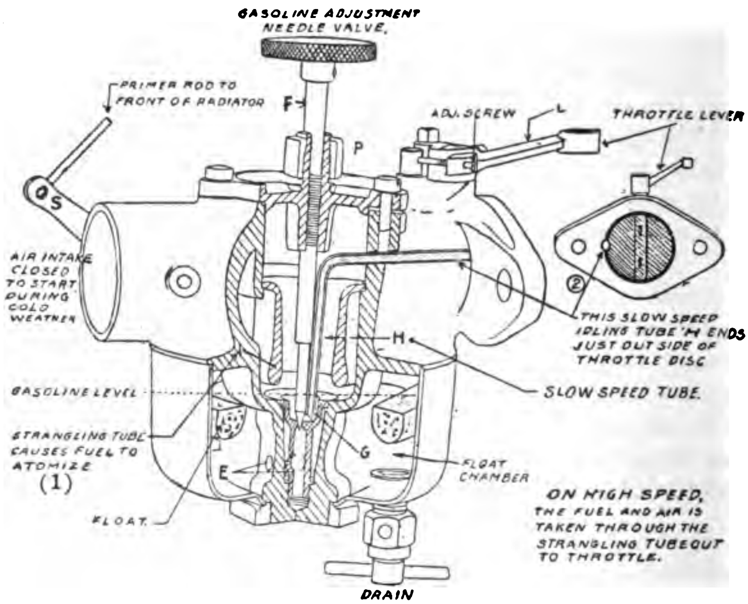


Fig. 90 — Holley model S

passing the float needle valve in entering the float chamber. From the float chamber the gasoline passes through the holes E to the needle valve F. The float level is so set that the gasoline rises past the needle valve and sufficiently fills the cup G to submerge the lower end of the small copper tube H.

The air enters from only one source, the air intake, there being no auxiliary air valves in the carburetor. All the air entering the car-

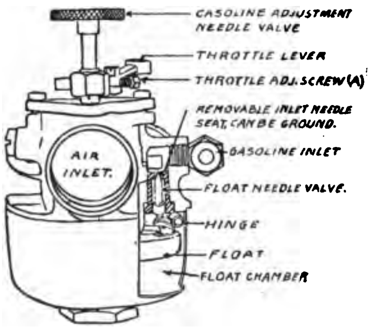


Fig. 91 — Side view of Holley

buretor must pass over the surface of the puddle of gasoline at G. The needle valve F regulates the amount of gasoline supplied to this well.

The tube H conducts gasoline from the well G to a point just beyond the throttle valve. This arrangement assists in supplying a mixture for running idle with closed throttle.

For facilitating starting in cold weather a choke is placed in the air passage to cause a slightly richer mixture.

The only adjustment on this carburetor is the needle valve which when turned to the right will cause leaner mixtures and when turned to the left will give richer mixtures.

CHAPTER XII

MAGNETISM

In order thoroughly to understand ignition, starting, and lighting systems, a preliminary knowledge of magnetism and elementary electricity is necessary. Only the most simple and fundamental electrical principles will be taken up but it is necessary that this and the following chapter be thoroughly understood or trouble will be encountered when the electrical apparatus used on a motor vehicle is studied. The preliminary discussion will be divided into two parts, a chapter on Magnetism and a chapter on Elementary Electricity.

The name magnet was first applied to certain brown colored stones taken from the earth which possessed the peculiar property of attracting small pieces of iron ore. When freely suspended by a string at the center this stone possessed the important property of pointing north and south, hence, it was given the name of "lodestone" (meaning leading stone). Hence, a magnet may be defined as a piece of steel or other substance which possesses the properties of attracting other pieces of steel or iron, and of pointing north and south when freely suspended in a horizontal position.

The compass needle is nothing more than a small bar magnet pivoted at the center so that it is free to turn in any direction like the lodestone. It will always point north and south, the same end pointing north each time. The ends of a magnet are termed its poles. The point midway between them is known as the neutral point. The end of a compass needle which points to the north is termed the north pole while the opposite end is called the south pole. The north pole of a magnet is generally marked in some manner to distinguish it from the south pole.

Magnets are of two kinds, permanent and temporary. Permanent magnets are either bar or horseshoe, the names arising from their shape. A permanent magnet must be a piece of steel which has been magnetized and which retains its magnetism indefinitely. A temporary magnet may be a piece of iron under the influence of a permanent steel magnet or temporarily magnetized by electric current (electro-magnet).

There is a distinction between substances which are magnetic and

which are nonmagnetic. Iron and steel are the only two substances which manifest these properties to any great extent. Two other metals, nickel and cobalt, are very slightly magnetic. For practical purposes all other substances such as copper, lead, gold, brass, bronze, wood, rubber, glass, etc., cannot be magnetized and are therefore nonmagnetic. Magnetic influences will take place through these substances.

A distinction must also be made between magnets and magnetic substances. A magnet attracts only at its poles, each of which possesses opposite properties. A piece of iron will be attracted by a magnet no matter what part of it is approached to the magnet but it does not possess fixed poles or a neutral point while a magnet always has two poles and a neutral point.

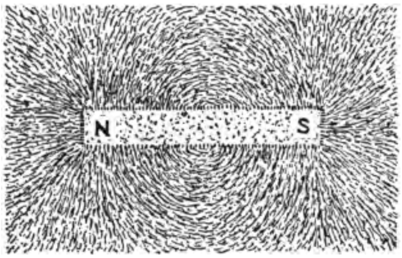


Fig. 92 — Field surrounding a bar magnet

Surrounding any magnet there exists what is known as the magnetic field. It is invisible and in fact is not perceptible to any of the senses. That it does exist can be proved by placing a piece of paper over the magnet and sifting iron filings over it. The magnetic force which permeates the space immediately surrounding the magnet causes the filings to arrange themselves in a certain definite manner indicating the nature of the force, its direction, and distribution. The magnetic force is not the same at all distances but decreases as the distance from the magnet increases. Figure 92 shows the magnetic field existing about a bar magnet while Fig. 93 shows the magnetic field of horseshoe magnet.

It is assumed that the magnetic lines of force (Figs. 92 and 93) emanate from the north pole of the magnet, pass through the surrounding medium, re-enter at the south pole and complete the circuit by passing from the south to the north pole through the magnet itself. Every line of magnetic force must have a complete circuit, hence, it is impossible to have a magnet with only one pole. Magnetic lines of force complete their circuits independently and never cut across or merge into each other. The fact that all the lines of

force pass through the magnet itself accounts for the concentration of magnetic force at the poles.

Lines of magnetic force will pass through some subtances more readily than through others. When a piece of iron is placed in a magnetic field the lines of force are bent out of their natural paths and pass through the iron. There are now more lines of force pas-

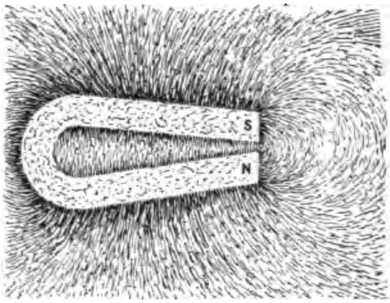


Fig. 93 — Field surrounding a horseshoe magnet

sing through the space occupied by the iron than when this space was occupied by air only. The property of any substance for conducting magnetic lines of force is termed its "permeability."

As shown in Fig. 94 a bar of iron placed in a magnetic field will cause distortion of the lines of force, many of which will pass through the iron. Magnetic lines of force always take the path of least resistance. If the piece of iron is arranged free to move in the field it will take up such a position as to accommodate through

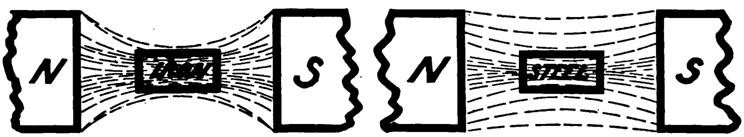


Fig. 94 — Permeabilities compared

itself the greatest possible number of lines of force. If instead of being a magnetic body it is a magnet, it will move under the influence of the magnetic field in which it is placed, not only so as to accommodate through itself the lines of force of the field but also in a particular direction so that its lines will be in the same direction as those of the field. Thus a magnet always tends to place itself so that lines of magnetic force enter its south pole and leave at its north pole.

Magnetic substances have the greatest permeabilities but the permeability of every magnetic substance is different. If a piece of steel is substituted for the soft iron (Fig. 94) fewer lines of force

will pass through the same space showing that the conducting power of iron is greater than that of steel. The permeability of iron may be as high as two thousand times that of air, that is, two thousand times as many lines of force will pass through the same space when occupied by iron as when occupied by air.

The path taken by magnetic lines of force in passing from any pole of the magnet through the surrounding medium and back to the same pole again is known as a magnetic circuit. The simple magnetic circuit is composed of a magnetic substance throughout its entire length, as for example, a magnetized iron ring or a horseshoe magnet with a keeper across its poles. A compound magnetic circuit is one in which the lines of force must pass through both magnetic and nonmagnetic substances, as for example, a horseshoe magnet without its keeper.

If two bar magnets are placed side by side and the resultant magnetic field is obtained by sifting iron filings on a paper covering them. It will be seen that the arrangement of the lines of force will depend upon whether opposite poles or like poles are adjacent.

When like poles are adjacent (Fig. 95) the lines of force striking against each other are distorted from their natural paths and compressed into a small space. This causes the magnets to be mutually repelled since the lines of force try to return to the regular positions that they normally occupy.

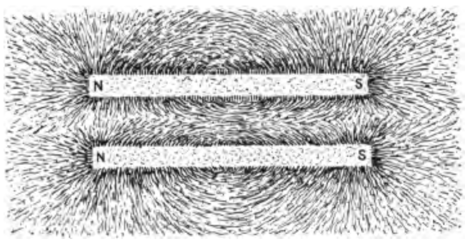


Fig. 95 — Field resulting with like poles adjacent

If unlike poles are adjacent (Fig. 96) the lines of force flowing from the north pole of each will enter the adjacent south pole since the steel offers a better path than air due to its greater permeability. This causes the lines of force to be stretched out of the regular positions and mutual attraction results since the lines of force tend to return to their normal positions. Thus it is seen that the like poles of magnets repel while unlike poles attract, both of which are the direct result of distortion of the magnetic field.

It is the same phenomenon that causes a piece of iron to be attracted by magnet. When a piece of iron or steel is near enough

to a magnet to be in its magnetic field the lines of force stretch out and pass through the piece of iron. This causes a distortion of the magnetic field and results in the iron or steel being drawn to the

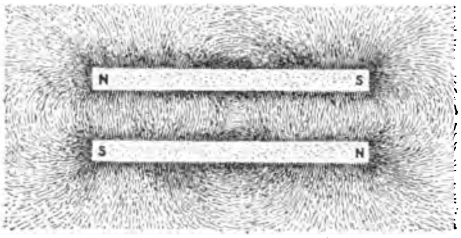


Fig. 96 — Field resulting with unlikes poles adjacent

nearest pole of the magnet (Fig. 97). While this is taking place the flow of lines of force through the piece of iron or steel causes it to become a temporary magnet. When any body is magnetized by the influence of a magnet it is said to be due to magnetic induction.

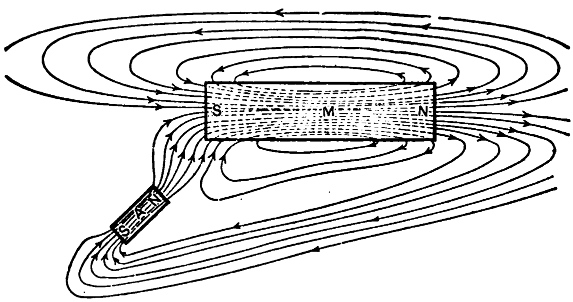


Fig. 97 — How magnet attracts iron

Contact between the inducing magnet and the body magnetized is not necessary and may take place through all nonmagnetic substances whether solids, liquids, or gases.

From the foregoing the following laws of magnets have been deduced:

1. Unlike poles of magnets are mutually attracted.
2. Like poles of magnets are mutually repelled.
3. Magnetic lines of force always take the path of least resistance.

If the polarity of a magnet is unknown it may be tested by using a compass needle or other small magnet of known polarity in accordance with the laws just stated.

The molecular theory of magnetism explains why a piece of iron or steel can be magnetized. All substances are composed of minute particles which are called molecules. The molecules composing

iron or steel are each individual magnets. When the iron or steel is not magnetized then the molecules arrange themselves promiscuously in the material, but according to the law of attraction between unlike poles local magnetic circuits are formed internally and there is no resulting external magnetism. Figure 98A illustrates the

A B

Fig. 98 — Molecules in magnetic substance

possible positions in which the particles composing a magnetic substance may arrange themselves when there is no external magnetism. It must be remembered that there may be as many as a million or more variously arranged magnetic circuits in even a very small piece of iron or steel. When the piece of iron or steel is placed in a magnetic field each little magnetized particle tends to place itself so that its axis is parallel to the direction of the magnetic field with its north pole pointing so that the lines of force must pass out at that end. This causes the closed magnetic circuits to be broken up and the particles to arrange themselves parallel to each other with their north poles all pointing in the same direction (Fig. 98B). The iron or steel now manifests external magnetism and will continue to do so as long as the molecules stay in this arrangement.

When under the influence of a strong magnetic field soft iron possesses greater attractive force than steel. When the magnetic field is removed, however, the steel possesses far superior attractive properties to the iron retaining them for the most part permanently. The soft iron is very slightly magnetized and what remains is commonly known as " residual magnetism." This difference is easily explained by the molecular theory of magnetism. The molecules of iron and steel offer considerable resistance to the force tending to turn them on their axes, the resistance of the steel molecules being much greater. It is difficult to turn them around, but once being turned around it is equally difficult for them to return to their original positions, due to the friction between themselves, hence, the resulting permanent magnetism in steel. On the other hand the molecules of soft iron turn very readily when under the influence of a magnetic field but resume their original positions when the magnetic field is removed as the friction between the molecules is much less, accounting for the temporary magnetism in iron. Not all of the molecules regain their exact original positions which is shown by the slight trace of magnetism always found in any piece of iron after having been magnetized.

It is impossible to see the molecules of iron or steel changing their relative positions under the influence of magnetism but by experiment this theory has been found to be correct. It is assumed that the molecules composing the iron or steel are regularly disposed, which necessarily has to be the case. When local magnetic circuits are formed, magnetization turns the molecules on their axes until they are arranged symmetrically. When they have all been turned around the bar is said to be saturated or completely magnetized. No matter how much additional magnetic force is available the magnetism of the bar cannot be further influenced.

Since magnetism depends upon the arrangement of the molecules in the magnetic substance their displacement will cause the partial or total loss of external magnetism. Any vibration tends to destroy permanent magnetism. For this reason permanent steel magnets must never be dropped or struck. Slight shocks are sufficient to demagnetize soft iron; steel retains with tenacity the properties of a magnet but its magnetic strength is impaired by shocks and will be entirely destroyed by a sufficient vibration.

Vibration may be produced in a substance by heat which causes the molecules to become more widely separated and reduces the internal friction between them. When sufficient heat is applied to a magnet it will entirely lose its magnetism because its molecules have become disarranged by the resulting vibration. For this reason heat must never be applied to permanent magnets.

When current flows through a conductor an electromagnetic field is set up about it. Every wire carrying a current possesses this magnetic field, which can be proved by bringing a compass needle near

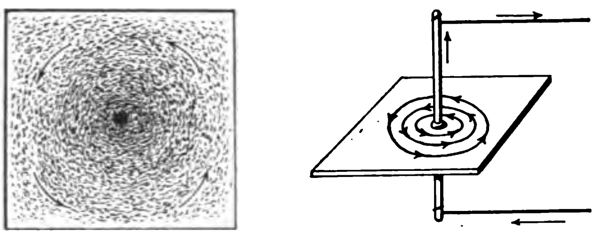


Fig. 99 — Field about current carrying conductor

the wire. The magnetic field of the wire acts on the magnetic field of the compass needle causing it to be deflected. If a wire through which current is flowing is passed through paper upon which iron filings are sifted they will arrange themselves in concentric circles with the wire at the center as shown in Fig. 99. Thus it is seen that the magnetic field around a straight wire carrying a current con-

sists of a cylindrical whirl of circular lines, their intensity decreasing as the distance from the wire increases as shown in Fig. 100. As is true of all lines of magnetic force these magnetic whirls do not merge, cross, or cut each other, but complete their circuits independently around the wire.

The direction of the magnetic whirls about the wire depends upon the direction the current is flowing through it. If the thumb

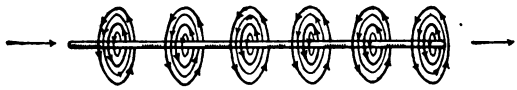


Fig. 100 — Magnetic whirls

of the right hand is placed along the wire in the direction in which the current is flowing the curved fingers will indicate the direction of the magnetic whirls about the wire. This may be checked by placing a compass needle near the wire which will show the direction of the lines of force by its deflection.

If a wire is arranged as shown in Fig. 101 so that it describes a half-circle above the cardboard its magnetic field will be shown by sifting iron filings on the cardboard. When current is passing

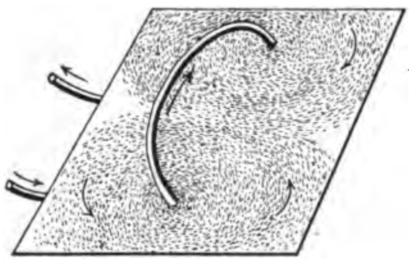


Fig. 101 — Direction of field through loop of wire

through the wire the iron filings arrange themselves circularly around the wire. It is seen that the magnetic lines of force pass down through the center of the loop, which can be confirmed by applying the right-hand rule.

If a wire is bent into a circular loop and current sent through it (Fig. 102) all the magnetic whirls about the wire will pass in through one side of the loop and out the other. If a compass needle is brought near the loop it will be attracted by the magnetic field of the loop just as it would be by a bar magnet. This is due to the fact that the side of the loop from which the magnetic whirls emerge acts as the north pole while the other side manifests south polarity.

If a coil of wire is wound into a helix and current sent through it, the result will be as shown in Fig. 103. Magnetic whirls are set up about each turn of the helix but the turns of wire being so near each other, the whirls instead of completing separate circuits

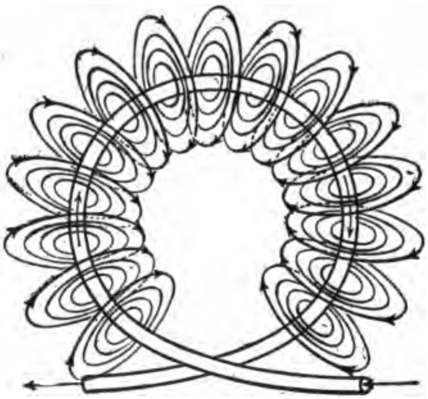


Fig. 102 — Whirls about loop of wire

join together looping all the turns composing the helix resulting in a continuous magnetic field. The total field is the sum of the magnetic lines of each individual turn, since it is the result of the whirls about adjacent conductors joining together and the sum of all the turns constitutes the field or total number of lines of force passing through the coil. The field set up by the coil is shown in

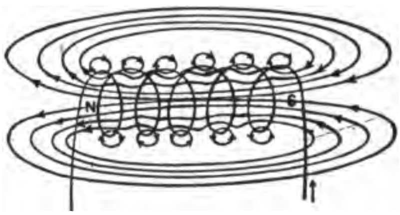


Fig. 103 — Field about helix

Fig. 103 and it will be seen that one end of the coil is the north pole while the other end is the south pole, just as was true of the two sides of the single loop of wire through which current was flowing. If the curved fingers of the right hand are placed about the coil of wire in the direction the current is flowing the thumb will indicate the north pole of the coil.

When a great many turns of wire are wound on a wooden or brass spool similar to the winding of a spool of thread the resulting coil is called a " solenoid."

An iron or steel bar inserted in a solenoid through which current is flowing is a much better conductor of the magnetic lines of force inside the solenoid than the air, so that the strength or attractive force of the solenoid is materially increased, though the magnetizing current is the same as before. An iron core introduced into a solenoid carrying a current becomes strongly magnetized and is called an electro-magnet (Fig. 104). The direction of the lines of force through the iron core of the solenoid is the same as their natural direction through the solenoid alone so that the laws of polarity

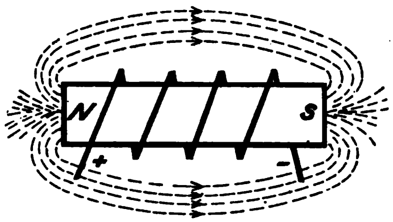


Fig. 104 — Electro-magnet

of the solenoid hold for the electro-magnet. The molecular theory of magnetism explains how magnetism is produced in the iron bar by passing current around it. The solenoid's magnetic field acts upon the molecules composing the iron bar causing them to arrange themselves producing an external field about the core. The magnetic field as set up by the current simply makes evident the latent magnetism of the iron. This molecular action also accounts for the permanent magnetism produced in a piece of steel, inserted in a solenoid after the current ceases, since the friction between the molecules prevents many of them resuming their original positions.

If a coil of wire is wound around an iron ring, and current sent through it, lines of magnetic force will flow around through the iron ring. If a small air gap is made in the ring by sawing out a section a compound circuit is formed and lines of force are compelled to pass through the air gap to complete their circuit so that north and south poles are produced. The lines of force through the iron part of the circuit are not nearly so dense as before, since the resistance of the circuit has been increased by introducing an air gap. If the removed section of the ring is now replaced and the ring covered with iron filings, while it is magnetized, a great many filings will be attracted at the two joints. This illustrates magnetic leakage. When magnetic leakage takes place with permanent magnets their strength is impaired. This should be guarded against especially when dismounting the magnets of magnetos.

CHAPTER XIII

ELEMENTARY ELECTRICITY

The term "electricity" has been applied to an invisible force known only by the effect it produces. Its exact nature is not known but the laws governing it are clearly understood and defined. These can best be explained by comparing its flow to that of water to which it is similar. However, it must be remembered that electricity is not a liquid and is only compared with water better to understand its flow.

Figure 105 shows two tanks *A* and *B* at the same level (*A* being filled with water) connected by a pipe in which is placed a valve. When the valve is opened slightly the water will flow from *A* into

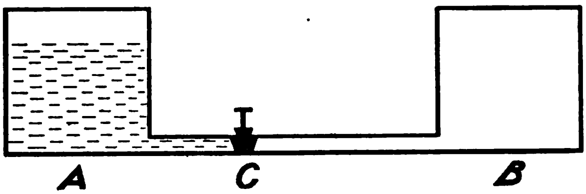


Fig. 105 — Water analogy to flow of current

B until the level of water in both tanks is the same. If the valve had been opened wider, the flow of water would have been faster because the larger opening offers less resistance to its flow. Had air been pumped into the top of tank *A* until a high pressure was obtained the flow of water through the pipe into tank *B* would have been still faster. Although the rate at which the water flows from tank *A* into tank *B* may vary, the quantity that flows is independent of the rate and depends only upon the difference in pressure between the two tanks. It is seen that pressure is required to cause water to flow and the rate of flow may be increased by reducing the resistance to its passage or by increasing the pressure.

In Fig. 106 the two terminals *A* and *B* of the dry cell are connected by a wire through the switch *C*. This may be compared to the two tanks connected by a pipe; the positive terminal *A* corresponding to the full tank, the negative terminal *B* corresponding to the empty tank, the wire to the pipe, and the switch *C* to the

valve. When the switch is closed current flows from *A* to *B* through the wire. The water flows from tank *A* to tank *B* because there is greater pressure at *A* than at *B*. Current flows from terminal *A* to terminal *B* because there is greater electrical pressure at *A* than at *B*.

Water pressure is usually measured in pounds per square inch, electrical pressure is measured in volts. The amount of water that flows may be measured in gallons or barrels, the amount of current that flows is measured in amperes. The smaller or longer the pipe the less will be the water flowing through it due to the increased resistance; similarly, the smaller or longer the wire the less will be the current flowing through it due to the increased resistance and this electrical resistance is measured in ohms.

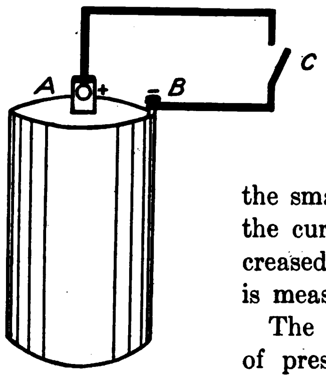


Fig. 106 — Simple electric circuit

The pound and the gallon are definite units of pressure and quantity both of which are familiar due to their common usage. Years ago in order to decide upon similar units for measuring electricity a committee was appointed made up of prominent scientists of the time. Dr. Ohm was chairman of this committee which met in his laboratory to decide the units by which electrical pressure, current, and resistance should be measured.

It was decided that the amount of pressure given by a certain cell should be the standard unit to which all other electrical pressure should be compared. The cell chosen was the Voltaic Cell and the amount of pressure this cell gave was named the "Volt." A six volt battery is one having six times the pressure of the Voltaic cell.

To obtain the unit of resistance it was decided to take a certain conductor and call its resistance the standard to which all others should be compared. The one chosen was a tube of mercury of definite size and length and the amount of its resistance to the flow of current through it was named the "Ohm." A conductor which has three ohms resistance is one that offers three times as much resistance to the flow of current as the original tube of mercury.

To obtain the unit of current it was decided to take this cell giving one volt pressure and connect its terminals with the tube of mercury and the amount of current that flowed was named the "Ampere." A circuit which has 10 amperes flowing through it is

one in which the current is 10 times as great as that caused to flow by a pressure of one volt through one ohm resistance.

Referring to Fig. 105 if the pressure is increased and the pipe size and length remains the same more water will flow; the same is true of electricty. If the pressure (voltage) is increased, more current (amperes) will flow through the circuit provided the resistance is not changed. If the pressure remains the same but the size of the valve opening is made smaller or the pipe decreased in size or increased in length, less water will flow; the same is true in electric circuits. If the pressure (voltage) remains the same and the wire is decreased in size or increased in length, increasing the resistance, (ohms) less current (amperes) will flow.

By experiment it has been found that the flow of electricity always depends upon the pressure and resistance of the circuit and that definite laws govern the amount of change in the flow of electricity for a given change of either of these. The relation between electrical pressure, current, and resistance is known as Ohm's Law and is as follows:

First: The strength of current flowing in any circuit is equal to the pressure in volts divided by the resistance of the circuit in ohms.

Second: The strength of current in any circuit increases or decreases directly as the pressure increases or decreases when the resistance is constant. With a constant pressure the current increases as the resistance is decreased and decreases as the resistance is increased.

$$\text{Current} = \frac{\text{Pressure}}{\text{Resistance}}$$

$$\text{Amperes} = \frac{\text{Volts}}{\text{Ohms}}$$

$$I = \frac{E}{R}$$

Problem 1.

With a six-volt battery and a circuit of two ohms resistance, how many amperes of current will flow in the circuit?

$$I = \frac{E}{R} = \frac{6}{2} = 3 \text{ amperes.}$$

Problem 2.

If the voltage is increased to 12 volts and the resistance is the same, how many amperes of current will flow?

$$I = \frac{E}{R} = \frac{12}{2} = 6 \text{ amperes.}$$

This proves that as the voltage increases, the current increases.

Problem 3.

If the resistance is increased to 3 ohms and the voltage is the same, how many amperes of current will flow?

$$I = \frac{E}{R} = \frac{6}{3} = 2 \text{ amperes.}$$

Proving that as the resistance increases the current decreases.

If the two tanks *A* and *B* (Fig. 105) are connected by a solid rod, no water can flow, a hollow rod or pipe is necessary to permit water to pass through it. If the terminals *A* and *B* (Fig. 106) of the dry cell were connected by a glass rod no current could flow, a metal rod or wire is necessary to permit electric current to pass through it. For this reason metals and other substances that electricity flows through easily, due to their low resistance, are called **conductors.**

To retain water, a pipe must be made of strong enough material to withstand the pressure exerted by the water passing through it. Similarly, to retain the current passing through it a wire must be surrounded by some material through which current cannot pass. Materials which offer considerable resistance to the passage of current through them are called nonconductors or **insulators.**

All conductors do not conduct electricity equally well since the resistance of every substance is different. Silver, copper, aluminum, steel, and iron are all good conductors and offer but little resistance to the flow of current. Materials such as glass, porcelain, rubber, silk, cotton, fiber, wood, and air offer a great deal of resistance to the flow of current and are classed as insulators. As in the case of conductors, all insulators do not resist the flow of current equally well.

Ohm's Law proves that the pressure in an electric circuit determines the amount of current that will flow. In other words pressure can overcome resistance and force current to flow. For this reason when the pressure is high in a circuit an insulator of much higher resistance must be used than would be necessary if the pressure were low.

For electric current to flow a path consisting of conductors must be provided. A break in the circuit will cause the current to cease flowing and it is said to be " open circuited."

The common circuits used in ignition, lighting, and starting work are series and parallel.

Series Circuit. — When electric lamps are connected as shown in Fig. 107 they are said to be in series because the current flows

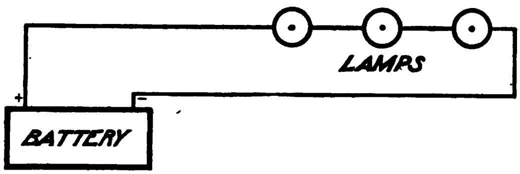


Fig. 107 — Series circuit

through each lamp to the next succeeding one, returning from the last one to the battery. In a circuit of this kind the resistance increases as the number of lamps is increased, decreasing the current if the pressure remains the same.

Parallel Circuits. — When electric lamps are connected as shown in Fig. 108 they are said to be connected in parallel. All the cur-

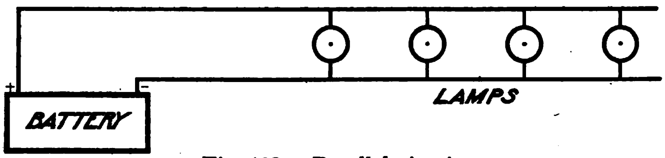


Fig. 108 — Parallel circuit

rent in this case does not have to flow through every lamp but part of it flows through each and back to the battery through the common return wire.

If two tanks *A* and *B* are connected as shown in Fig. 109 and valve *C* is opened, a certain amount of water will flow between

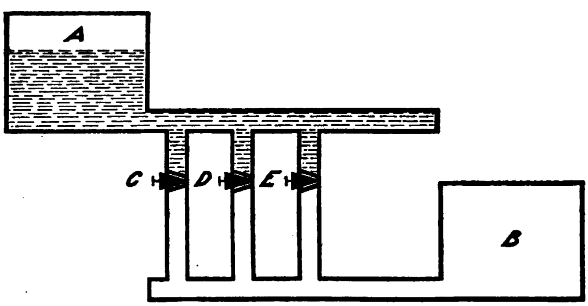


Fig. 109 — Water analogy to parallel circuit

them. If valve *D* is opened more water will flow because another path has been opened, reducing the total resistance. If valve *E* is opened a still greater quantity of water will flow.

This is the same arrangement as shown in Fig. 108 and as more lamps are added the total resistance of the circuit is reduced and more current flows if the pressure remains the same.

Lights on cars are usually connected in parallel since turning on additional lights will not require a change of voltage. Also, the burning out of one light will not put out any of the others.

CHAPTER XIV

BATTERIES

The simplest method of producing electric current is by chemical means. A simple primary cell may be made by placing two dissimilar metals in an acid or alkaline solution. Figure 110 shows a plate of zinc and a plate of copper placed in a glass jar containing a solution of sulphuric acid. If the plates are connected by a piece of wire a chemical reaction takes place between the zinc plate and the acid causing the zinc to be gradually wasted away. This causes the terminal at the copper plate to be positively charged, resulting in a flow of current from the terminal at the copper plate through the wire to the terminal at the zinc plate. This action will continue as long as any of the zinc is left or until the acid has become so weak that its power to attack the zinc is exhausted. If the connection between the plates is broken at any time the chemical reaction stops and will only continue when the circuit is again made. This is the simplest form of chemical cell and illustrates the fundamental principle underlying the operation of all chemically produced electric current.

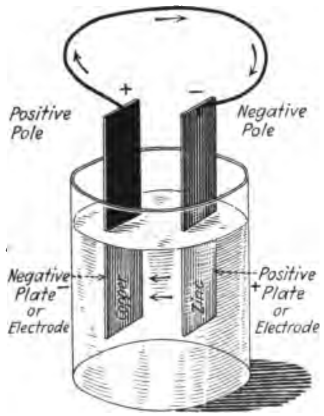


Fig. 110 — Simple cell

There are many kinds of cells for chemically producing electric current but there are only two which are applicable for ignition on motor-propelled vehicles. These are the Dry Cell and Storage Cell and are the only types which will be discussed in this chapter.

Dry Cell. — The active elements of the dry cell consist of a zinc shell *1* in the center of which a carbon rod *3* is placed (Fig. 111). Next to the zinc shell is placed blotting paper *2* which is soaked with the active chemical (usually salamoniac or zinc chloride) called the electrolyte. The carbon rod is surrounded by some depolarizing material (usually manganese dioxide) and the space between is filled with a compound *4* usually kept secret by the manufacturer. To make the cell watertight it is sealed at the top with pitch *5*.

The zinc shell is attacked by the active chemical and is eaten away. During this chemical action hydrogen gas is liberated and collects on the carbon rod in small bubbles. These would insulate it if it were not for the action of the depolarizer which combines with the hydrogen to form water. The voltage of a dry cell of the kind just described is approximately $1\frac{1}{2}$ volts on open circuit when new and in good condition irrespective of the size of the cell. A large cell of the same construction will give more current than a small one but the voltage will not be increased. The ordinary size of dry cell will give 20 to 35 amperes of current when the circuit is first closed. The cell will deliver this maximum amount of current for only a very short length of time. For this reason dry cells are only suitable for intermittent circuits.

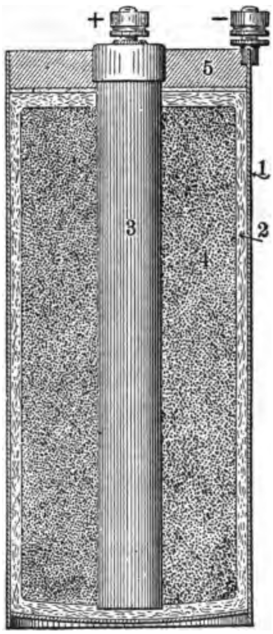


Fig. 111 — Cross-section through dry cell

A battery consists of two or more cells which are connected together to obtain suitable voltage and current. The arrangement or connection will depend upon the requirements of the circuit for which the battery is to supply current.

There are three methods of connecting dry cells to form batteries; series, parallel, and series-parallel.

Figure 112 shows a battery composed of dry cells connected in series. The positive terminal of one cell is connected to the negative of the next succeeding cell and the line is connected to the remaining terminals. When cells are connected in series the voltage of the battery is equal to the sum of the volt-

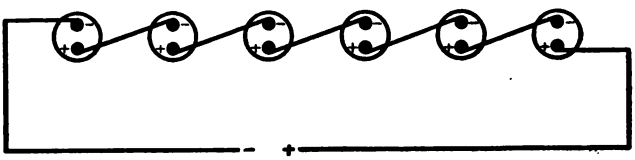


Fig. 112 — Cells in series

ages of all the cells. That is, the voltage of a battery, is the voltage of one cell times the number of cells when each cell has the same voltage. The amperage of the battery will be equal to the amperage of one cell. For example, if each cell in Fig. 112 has a

strength of $1\frac{1}{2}$ volts and 25 amperes, the strength of the battery will be 9 volts and 25 amperes.

Figure 113 shows a battery of dry cells connected in parallel. The positive terminals of all the cells are connected to one line and all the negative terminals to the other line. When cells are connected in parallel it is necessary that every cell be of the same voltage. The voltage of the battery will be equal to the voltage of one cell. The amperage will be equal to the sum of the amperes of all the cells. That is the amperage of the battery is equal to the amperage of one cell times the number of cells when the amperage of each cell is the same. For example, if the cells in Fig. 113 are each of $1\frac{1}{2}$ volts and 25 amperes the strength of the battery will be $1\frac{1}{2}$ volts and 150 amperes.

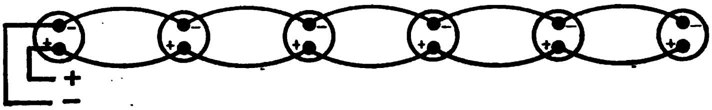


Fig. 113 — Cells in parallel

These two methods of connecting cells to form batteries are the most common; however, when increased voltage and amperage are both desired the cells must be connected in series-parallel.

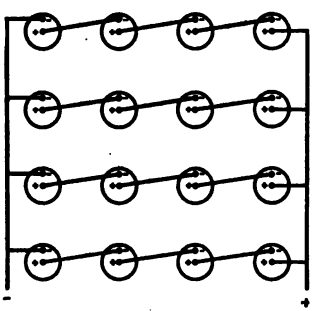


Fig. 114 — Cells in series parallel

Figure 114 shows a battery of dry cells connected in series-parallel. It is made up of sets of cells connected in series, each of these sets being connected in parallel. The voltage of this battery is equal to that of each set of cells connected in series. The amperage is equal to the sum of the amperes delivered by each set. For example, if the cells in Fig. 114 are each of $1\frac{1}{2}$ volts and 25 amperes the strength of each set in series will be 6 volts and 25 amperes. The strength of the battery will therefore be 6 volts and 100 amperes.

Storage Batteries. — These batteries are almost without exception the only kind used on modern motor-propelled vehicles. The reason for this is the adoption of starting and lighting systems as standard equipment on most motor vehicles.

In the storage cell the current results from chemical action the same as in the simple primary cell. The plates or electrodes are usually built upon grids which are perforated as shown in Fig. 115.

The group of plates connected to the positive terminal of the cell consists of grids filled with a paste of lead peroxide characterized by its brown color. The group of plates connected to the negative terminal of the cell consists of grids filled with metallic lead of a spongy nature and is dull gray in color. These plates are arranged in the cell so that the positive and the negative plates are alternative. Between the plates are placed separators which are to prevent the plates of the positive and negative groups from coming into contact. The separators must be porous to allow the solution to pass through freely and are usually made of specially treated wood or hard rubber. The jar or container in which the plates are placed is usually made of hard rubber which is not affected by the acid. The assembly of plates and separators (Fig. 116) is placed in this jar or container and a solution of sulphuric acid and distilled water is added until the level of the liquid in the jar covers the tops of the plates. The cell is sealed by a cover of hard rubber through which the positive and negative terminals project (Fig. 117). A filler cup is provided through which an air vent is left for the escape of gas which may be formed in the cell.

Fig. 115 — Grid

Storage cells are connected in series to form batteries which will give higher voltage. The voltage of a storage cell is usually considered two volts since this is the average value. If greater amperage is desired the size of the cell is increased. The rating of storage batteries is usually given in volts and ampere hours. Ampere hours means that if the battery is discharged at a certain definite rate it will give a certain current for so many hours. If 10 amperes was the rate of discharge upon which it was rated, a 6 volt 120 ampere-hour battery would be one having 3 cells connected in series and would give 10 amperes of current for 12 hours. If the battery was discharged at a high rate, 20 amperes, it would not last for 6 hours and likewise if discharged at a low rate, 5 amperes, it would usually last much longer than 24 hours. Therefore, the ampere-hour life of a battery is governed by the rate at which it is discharged.

When a storage battery is discharging a chemical reaction takes

place. The sulphuric acid (H_2SO_4) is broken up into two parts, H_2 and SO_4. The hydrogen is liberated at the lead peroxide plates (PbO_2) reducing them to lead oxide (PbO) which combines with parts of the sulphuric acid to form lead sulphate ($PbSO_4$) and water (H_2O). The SO_4 is liberated at the spongy lead plates (Pb) and combines with them to form lead sulphate ($PbSO_4$). During this

Fig. 116 — Plate assembly

process the electrolyte grows less concentrated because of the absorption of SO_4 by the spongy lead plates.

When the battery is being charged by passing current through it in the opposite direction the chemical action just described is reversed. The lead sulphate on one plate is converted back to lead peroxide, the lead sulphate on the other plate is reduced to spongy lead, and the electrolyte becomes more dense due to the increased amount of sulphuric acid. The following is the chemical reaction which takes place in a storage cell while discharging and being charged.

DISCHARGING

$$\begin{array}{lllll} \text{Positive plate} & PbO_2 + H_2 + H_2SO_4 & = PbSO_4 + 2\ H_2O \\ & \qquad\quad \uparrow & \\ \text{Negative plate} & Pb \ + \ SO_4 & = PbSO_4 \end{array}$$

CHARGING

$$\begin{array}{lllll} \text{Positive plate} & PbSO_4 + O + H_2O & = PbO_2 + H_2SO_4 \\ & \qquad\quad \downarrow & \\ \text{Negative plate} & PbSO_4 + H_2 & = Pb + H_2SO_4 \end{array}$$

The current in a storage cell results from chemical action just as in any other cell. When a dry cell is exhausted it is thrown away while the storage cell is restored to normal condition by passing

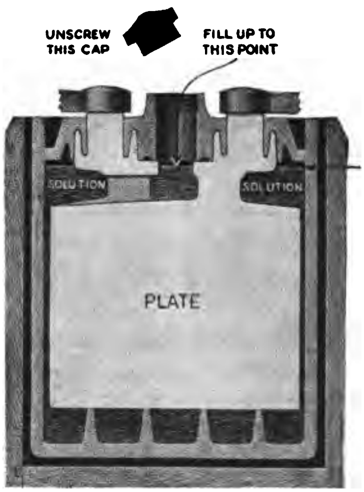


Fig. 117 — Cross-section through storage cell

direct current through it from some outside source. By this process the chemical reaction which took place upon discharge is reversed restoring the elements to their original condition. It is erroneous to say that electricity is stored in a storage cell. The storage cell is a means of converting electrical energy into chemical energy during charge and chemical energy into electrical energy during discharge.

During discharge some of the sulphuric acid combines with the plates causing the solution to have a greater proportion of water to sulphuric acid, this proportion increasing as the discharging continues. The relative amounts of acid and water can be deter-

mined by reading the specific gravity of the solution. This is accomplished by the use of an instrument called a hydrometer contained in a syringe (Fig. 118). The electrolyte is drawn up into the syringe by the bulb and the hydrometer will sink to a greater or less amount depending upon the amount of sulphuric acid in the

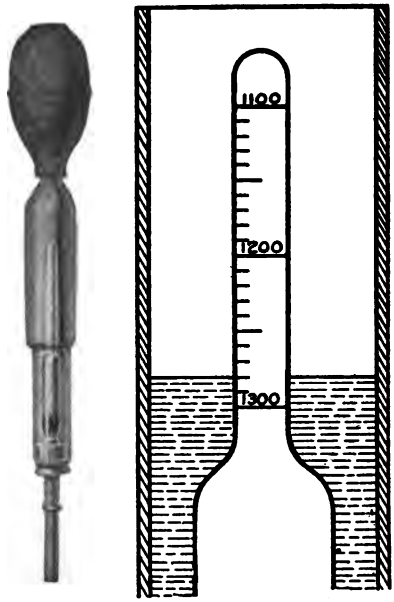


Fig. 118 — Hydrometer and syringe

solution. If the hydrometer reads 1.280 it indicates that the liquid is 1.280 times as heavy as water. The scale of the hydrometer is read on the stem at the surface of the liquid when the hydrometer is floating in it (Fig. 118).

The readings of the hydrometer show the condition of the battery in accordance with the following table:

Reading	Condition
1.280–1.300	Full charge
1.250	¼ Discharged
1.215	½ Discharged
1.180	¾ Discharged
1.150	Discharged

During the chemical reaction which takes place in charge and discharge heat is generated and causes the loss of some of the water

but there is no loss of sulphuric acid. For this reason when the solution in the cells gets below the top of the plates more distilled water must be added. When adding distilled water care must be taken not to fill the cell full. This is apt to result in the loss of some of the solution through the vent, the acid attacking the metal parts causing them to become corroded and eaten away. If acid is spilled or slops out, the battery box will soon be destroyed. In addition to this if some of the solution is spilled there is no way to determine how much acid has been lost and it cannot be replaced with certainty.

Never take readings of the specific gravity of a cell immediately after adding water to a cell. When taking a hydrometer reading with a syringe be sure to return the solution to the same cell from which it was taken. **Under no circumstances should acid of any kind be added to a cell** which has once been put in operation.

When a battery is to be prepared for service remove the black hard rubber vents which are standard equipment and remain on the battery when in service. The cells should be filled to the bottom of the vent holes with 1.275 specific gravity electrolyte at 70° F. 1.275 specific gravity electrolyte consists of approximately two and one half parts by volume of distilled water and one part by volume of chemically pure sulphuric acid. The acid should be poured into the water and allowed to cool below 90°F. before being used. Never fill the battery with electrolyte above 90°F.

Allow the battery to stand for twelve hours and add more 1.275 specific graviy acid if necessary to bring the level up to the bottom of vent holes. Then start charging at the finish rate stamped on the name plate for not less than 72 hours or until the specific gravity of the electrolyte stops rising. At the end of charge each cell should be gassing freely and the voltage should read at least 2.4 volts per cell.

While charging add distilled water to replace any electrolyte lost by evaporation. If during the charge the temperature in any one cell exceeds 110°F. the current must be reduced until the temperature falls below 100°F. This will necessitate a longer time to complete the charge, but must be strictly adhered to.

The batteries are now completely charged and the specific gravity of the electrolyte should be between 1.290 and 1.310 in each cell. If above 1.310 remove a little electrolyte and add the same amount of distilled water while the battery is left charging (in order to thoroughly mix the solution) and after three hours if the electrolyte is within the limits, the cell is ready for service. If the specific gravity is below 1.290 remove a little electrolyte and add the same

amount of 1.400 specific gravity electrolyte and leave on charge as before. 1.400 specific gravity electrolyte consists of seven parts chemically pure sulphuric acid and nine parts distilled water by volume. The acid should be poured into the water and allowed to cool below 90°F. before being used. The standard vent plugs are now inserted and the battery is ready for service.

A storage battery requires constant care and attention and if treated properly will give most satisfactory service but if neglected will cause constant trouble and soon become unserviceable. A battery should be held rigid in the battery box to prevent spilling of the solution. There should be an air space between the battery and the battery box for ventilation. The interior of the battery box must be kept clean and dry and the terminals should be coated with vaseline or grease. If any acid is spilled on the battery, wipe it up with waste wet with ammonia. Never lay waste on top of a battery since this practice is apt to cause short circuits between the cells.

A battery should be inspected once each week in warm weather and once every two weeks in cold weather to ascertain its condition. If the solution is low **distilled** water should be added to cover the tops of the plates. Be very careful not to add **too much** water. At each inspection several hydrometer readings of each cell must be taken before adding any water. After testing the electrolyte be sure to replace it in the cell to which it belongs. If the specific gravity of one cell shows it to be considerably lower than the others at several successive readings this indicates that the cell is out of order. Likewise, if one cell requires more water than the others it shows that the jar is cracked.

Never allow the battery to get completely discharged because it will sulphate the plates in the battery. If the generator on the car does not keep the battery up to a reading of 1.200, at least part of the time, the battery should be removed and charged by some outside source.

If it is found that the batteries read very high at several successive readings it is best to use some of the current either by running the engine for a few minutes with the starting motor or by leaving the lights turned on until the battery is partially discharged.

If for any reason an extra charge is needed and the battery is charged from some outside source only direct current can be used. Limit the current to the proper charging rate by connecting a suitable resistance in series with the battery. Incandescent lamps are suitable for this purpose. Connect the positive battery terminal to the positive charging wire and the negative to the negative wire.

If reversed, serious injury to the battery will result. The proper charging rates are generally marked on the name plate of a battery. When charging start at the starting rate and continue to charge at this rate until the cells gas freely. Then reduce the charging to the finish rate and continue for 6 hours. The specific gravity at the end of the charge should read 1.280 to 1.300. If it does not reach this point continue the charge at the finish rate until the specific gravity stops rising. If the specific gravity still does not reach 1.280 it indicates that the battery needs special attention, the trouble probably resulting from loss of acid or sulphating or buckling of one or more plates. If during charging the temperature of any cell exceeds 110°F. the charging rate must be reduced.

During warm weather the temperature of the battery must be watched and if the solution if found to be 110°F. the lights should at once be turned on so as to reduce the current passing into the battery. Batteries overheat when nearly fully charged if a high rate of charge is maintained.

During extremely cold weather it is essential that the battery be kept fully charged in order to prevent freezing of the solution. The following table shows the temperature at which electrolytes of different specific gravity will freeze.

Sp. Gravity	Freezing Pt.
1.150	20° above O
1.180	0°
1.215	20° below O
1.250	60° below O

When a battery is not to be used for a short period of time, such as one or two months, it should be given a fresh charge once a month and a thorough charge before being put back into active service. In case a battery is to be shipped it should be fully charged, the electrolyte emptied out, and the plates thoroughly washed in distilled water and dried. It is put in operation again as previously described.

Figure 119 shows a very good charging board which is suitable for charging a storage battery from 110-volt direct current mains. The charging is controlled by the number of lamps in the circuit. The lamps being connected in parallel, more current will flow as the number of lamps is increased.

Batteries are constructed for the particular service for which they are to be used. A battery constructed for lighting purposes only, should never be used with starting systems, as the heavy discharge rate will cause serious damage to the battery.

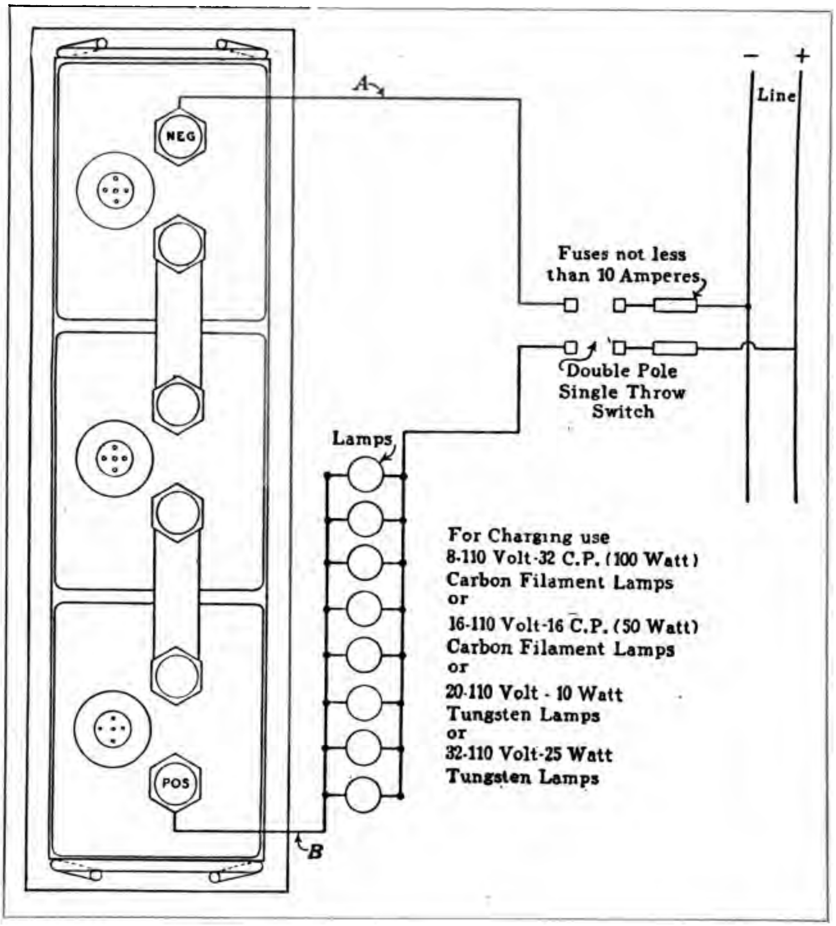


Fig. 119 — Charging board

CHAPTER XV

INDUCTION

When electricity is produced by chemical means the voltage is low and therefore is not suitable for ignition systems unless the voltage is increased in some manner. High voltages are obtained by electro-magnetic induction and this method of obtaining higher voltages is applied to ignition systems. To thoroughly understand ignition it is necessary to study the elementary principles underlying induction which will be taken up in this chapter.

The exact nature of magnetism and electricity is still unknown but much has been discovered concerning the relation existing between them. It has been shown that whenever there is a current of electricity flowing there is always a magnetic field present. This magnetic field lasts as long as the current continues to flow, showing that there is a definite relation existing between magnetism and electricity. Since electricity produces magnetism it is reasonable to expect magnetism to produce electricity and it has been found by experiment that this is true.

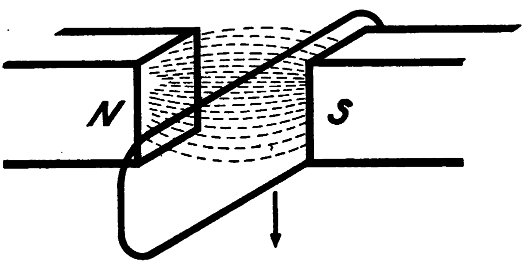


Fig. 120 — Electro-magnetic induction

If a magnetic field is present and a loop of wire is moved so as to cut the magnetic lines of force (Fig. 120) a current is caused to flow through the conductor. Currents generated in this way are known as induced currents and the phenomenon termed electro-magnetic induction. The same result is obtained if the conductor is kept stationary and the magnetic lines of force moved so as to be cut by the conductor.

The direction of the flow of the induced current in the conductor will depend upon the direction of the lines of force and the direction

in which the magnetic field is cut. A simple method of determining this when the direction of motion and direction of the lines of force are known is by the means of the right-hand rule. Place the thumb, the first, and the second fingers of the right hand all at right angles to each other (Fig. 121) and in such relation to the conductor that the first finger points in the direction of the lines of force, and the thumb in the direction of motion. The second finger will then indicate the direction of the induced current. Applying this rule to Fig. 121 in which the wire is being moved upward and the lines of force flow from the north pole as indicated, the current is found to flow through the conductor as indicated by the arrow.

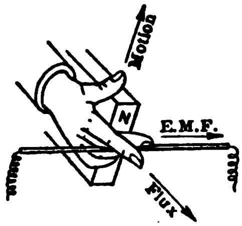


Fig. 121 — Right-hand rule

The strength of the induced voltage in a conductor when it is cutting lines of force is proportional to the rate at which the lines of force are cut. If a circuit of several turns of wire is substituted for the single loop used in Fig. 120 the induced voltage will be greater. This results because each loop now cuts as many lines of force as were cut by a single loop, increasing the total number of lines of force cut. If the strength of the magnet is increased it will cause more lines of force to be set up so that the same number of turns moving through the field would cut a greater number of lines of force thus causing an induced current of higher voltage. The induced voltage will, therefore, depend upon the following factors:

1. The strength of the magnetic field.
2. The speed or rate of cutting lines of force.
3. The number of turns of wire cutting the lines of force.

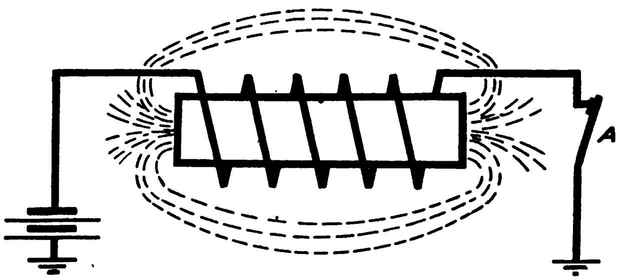


Fig. 122 — Self induction

Self Induction. — If a coil of wire is placed about a core of soft iron, and current sent through the coil, magnetic lines of force will be set up. If the circuit is broken by opening the switch A

(Fig. 122) the current ceases to flow and the magnetic field will collapse. In collapsing the lines of force cut the winding of the coil inducing current in the coil which is called self induction. Self induction is defined as " the cutting of a wire or coil by the lines of force set up by the current flowing through it." Applying the right-hand rule it will be seen that the direction of flow of the induced current is in the same direction as the interrupted flow of current. When applying the right-hand rule do not take the motion of the lines of force as the direction of motion but take the equivalent motion of the conductor.

The induced voltage will be much higher than that of the current which set up the magnetic field. When the switch is opened this high induced voltage causes an arcing between the separating contacts. When self induction is present in an ignition system the induced voltage is approximately 200 volts, which is not sufficiently high to jump a fixed air gap of any appreciable size but will cause a following arc between separating points.

When the circuit is made the magnetic field building up also cuts the winding. By applying the right-hand rule it it will be seen that the induced current opposes the flow of the current setting up the field. This is termed counter electro-motive-force and its opposition to the increasing current in the coil causes the field to build up very slowly.

Mutual Induction. — If two coils of wire are placed about an iron core and current caused to flow through one of them (Fig. 123) a magnetic field will be built up about the core. The coil through

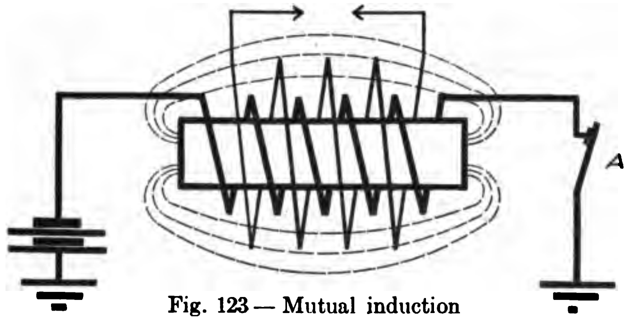


Fig. 123 — Mutual induction

which this current is caused to flow is known as the primary and the other coil is called the secondary. If the switch A is now suddenly opened this magnetic field collapses and **both** windings are cut out by lines of force. This causes currents to be induced in both the primary and secondary windings; that in the secondary is said to be mutually induced current. Mutual induction is de-

fined as "the cutting of a wire by lines of force set up by current flowing through another wire or coil." **There is no electrical connection between the primary and secondary windings.** By applying the right-hand rule it will be seen that the induced current in the secondary flows in the opposite direction to the inducing current in the primary when the primary circuit is made, and in the same direction when the primary circuit is broken.

When the primary circuit is made a counter E. M. F. results which tends to oppose the building up of the field. The mutually induced current in the secondary sets up a field which tends to strengthen this counter E. M. F., further retarding the building up of the magnetic field. Thus the current flowing in the primary has to overcome the counter E. M. F. due to the induced current. Hence the rate at which the field builds up is slow and the resulting voltage in the secondary will be correspondingly low. When the primary circuit is broken, however, there is no counter E. M. F. in the primary; the result is a sudden collapse of the field and a consequently high voltage is induced in the secondary.

When high voltages are desired they may be obtained by mutual induction employing a much greater number of turns of wire in the secondary winding than in the primary. The voltages in the primary and secondary windings vary directly as the number of turns of wire in each, while the current varies inversely as the number of turns of wire. For this reason fine wire is used for the secondary windings and much heavier wire for the primary.

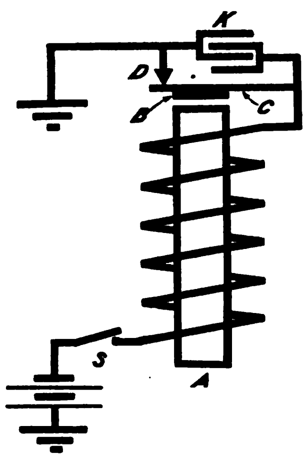


Fig. 124 — Simple vibrator

Figure 124 shows a simple vibrator which is used for making and breaking a circuit. It consists of a coil wound about a soft iron core *A*; opposite one end of this core is placed a small piece of soft iron *B* attached to a spring *C*. An adjusting screw *D* is in contact with the spring when in its normal position.

One side of the battery is grounded while the other is connected through the switch *S* to the coil, the other end of the coil is attached to the spring *C* and the screw *D* is grounded.

When the switch is closed a magnetic field is set up magnetizing the core. This attracts the iron *B* breaking the circuit at *D*. This causes the core to be demagnetized and the spring *C* returns to

its normal position again closing the circuit. This operation will be repeated over and over as long as the switch S is closed. Thus the circuit is automatically made and broken.

When the circuit is broken the collapse of the magnetic field induces a current in the winding. The voltage of this self-induced current is sufficient to cause an arc to follow the separating points at D each time the current is broken. The arcing burns and pits the contact points increasing the resistance of the circuit. To prevent this a condenser K is connected in parallel with the contact points as shown in Fig. 124. When the circuit is broken the flow of induced current passes into the condenser charging it. This momentarily diverts the flow of current from the contact points allowing them to separate sufficiently to prevent a following arc.

A condenser is usually constructed of sheets of silver, tin, or lead foil, alternate sheets being connected to common terminals and separated from each other by some insulating material such as mica or specially treated paper (Fig. 125).

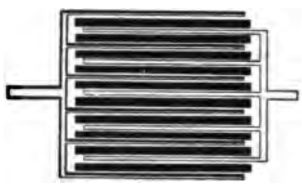


Fig. 125 — Condenser

The capacity of a condenser depends upon the total area of the plates and the distances these plates are separated by the insulating material. When a condenser is used on ignition systems it is necessary to have it of proper capacity. This is governed by the amount of self-induced current in the circuit in which it is placed.

CHAPTER XVI

BATTERY IGNITION SYSTEMS

After experimenting for many years with different systems of ignition it has been found that the most reliable and satisfactory is the high tension "jump spark" system. There are many means employed to produce the necessarily high voltage required to jump a set gap, all of which are based on the principle of mutual electromagnetic induction. Ignition systems are classified under two general headings, Battery Ignition Systems and Magneto Ignition Systems. Battery ignition systems employ a coil to obtain the necessary voltage receiving the current for the primary from some outside source. This type of ignition will be discussed in this chapter.

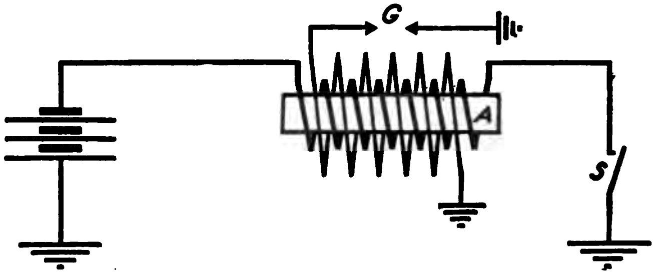


Fig. 126 — Induction coil

Figure 126 shows a core A wound with a primary and secondary winding, one end of the primary being connected to the battery, the other side of which is grounded. The other end of the primary is connected to ground through a switch S. One end of the secondary is grounded and the other end led to a spark gap G, the other side of which is grounded.

When the switch is closed a magnetic field is set up about the core which collapses when the switch is opened, causing a mutually induced current to flow in the secondary. In ignition coils a great number of turns of wire are used on the secondary to obtain sufficient voltage to jump set air gaps.

As already explained in timing the spark must occur at a certain definite time during the operation of the engine. This requires that the primary circuit be made and broken to obtain the mutually

induced current in the secondary at the proper time. To accomplish this some circuit breaking device positively driven by the engine and timed with it must be used. Such a device is known as a "Timer" and its object is to make and break the primary circuit at the proper time.

There are two types of timers, that shown in Fig. 127 where the contacts are together except when separated by the cam, and that shown in Fig. 128 where the contacts are separated except when closed by the cam. The first type allows the current to flow through the primary except for the short period when the circuit is broken. The circuit being closed the greater part of the time the current

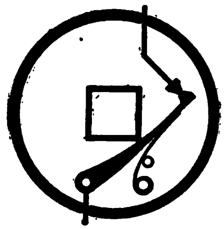


Fig. 127 — Closed circuit timer

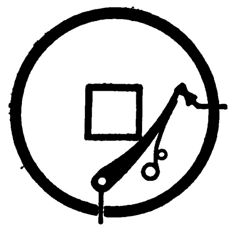


Fig. 128 — Open circuit timer

consumption will consequently be large. The other type allows current to flow through the primary only for an instant which materially reduces the current consumption. When the circuit is made in this construction the flow of the current through the primary is opposed by the counter E. M. F. resulting from self-induction and the complete building up of the magnetic field takes a definite length of time. At slow speed there will be enough time elapsed before the circuit is again broken for the complete building up of the field. As the speed increases there is not sufficient time and the field will still continue to build up due to the inertia of the current after the circuit has been broken. Therefore, the collapse of the field and consequent mutual induction in the secondary does not occur for some time after the primary circuit has been broken. This is known as "electrical lag" and is measured in degrees of revolution of the crank shaft between point of break and point of spark. On some ignition systems this lag has been measured and found to be as great as 35 degrees at 2,000 R. P. M. of the engine.

If the cams (Fig. 127 and 128) are turned clockwise and the housings carrying the contact points are turned anti-clockwise the circuit will be broken earlier. This will advance the time at which the spark takes place in the cylinder and is termed "advancing the

spark." If the housings were moved in a clockwise direction it would cause the circuit to be interrupted later and consequently the spark would take place later in the cylinder. This is termed "retarding the spark." The general rule is that when the housing is turned in the opposite direction to the rotation of the cam the spark is advanced and when turned in the same direction the spark is retarded.

It will be remembered from valve timing that ignition is advanced in accordance with the speed of the engine. Hence, it is necessary to limit the movement of the timer housing. The method of accomplishing this varies with the type of timing connection employed.

The cam used in a timer may have any number of noses but it generally has as many as the engine has cylinders. This makes it necessary to drive the timer at half engine speed on a four-cycle engine. To determine the speed at which any timer should be driven the following formulae are used:

For four-cycle engine,

$$\text{Speed} = \frac{\text{Number of Cylinders}}{2 \times \text{number of noses on cam.}}$$

For two-cycle engines,

$$\text{Speed} = \frac{\text{Number of Cylinders}}{\text{Number of noses on cam.}}$$

Applying the formula for four-cycle to a four-cylinder engine having a four-nosed timing cam:

$$\text{Speed} = \frac{4}{2 \times 4} = \frac{1}{2} \text{ engine speed.}$$

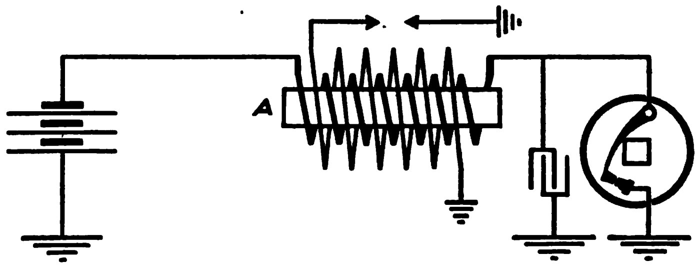


Fig. 129 — Induction coil with timer and condenser

In Fig. 129 the switch has been replaced by a timer and a condenser has been connected in parallel with it. The condenser is

necessary just as in the case of a vibrator the self-induction otherwise causing arcing at the contact points.

If continued arcing at the contact points were permitted burning and pitting would result which would increase the resistance of the primary circuit. Any increased resistance in the primary circuit reduces the amount of current flowing, thus weakening the magnetic field. This reduction of the lines of magnetic force will correspondingly reduce the induced voltage of the secondary and material reduction of the secondary voltage will affect the spark or stop it altogether. Low secondary voltage is generally traceable to the primary circuit.

For the timer to operate properly it is necessary that the contact points be in proper adjustment. The gap should be 0.5 mm. or 0.020 inch when the points are fully separated. If the gap is too small arcing will take place causing pitting of the contact points.

The timer controls the instant at which the spark occurs and must operate in synchronism with the engine. However, if the system is to be used on a multi-cylinder engine some provision must be made to distribute the secondary current to the spark plugs in their proper firing order. To accomplish this a distributor is used.

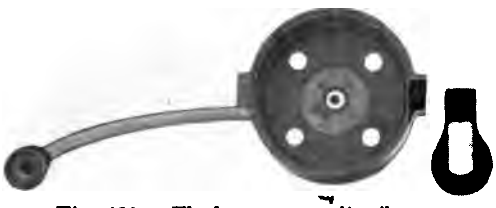


Fig. 130 — Flush segment distributor

Figure 130 shows one common construction of distributor. The current is led to the center terminal which is in contact with the rotor. This rotor is made of insulating material and has a brass tube running through it in which fits the carbon brush which conducts the current to the segments. The housing is made of insulating material with brass segments inserted in it and flush with the inner circumference with which the carbon brush of the rotor makes contact. The segments are connected by brass tubes through the insulating material to the terminals on the outer surface of the distributor. As the rotor revolves it makes contact with the segments in order and the terminals connected to these segments are wired to the spark plugs in their proper firing order. It is necessary to have this rotor positively driven by the engine and at such a speed

that it will be on the proper segment when the primary circuit is broken by the timer.

As it is necessary to have a segment for each cylinder the speed is figured by using the same formulae as employed in determining the speed of a timer. It will be found that the rotor always turns half engine speed on a four-cycle engine and engine speed on a two-cycle engine.

As previously stated timers are usually designed with cams having the same number of noses as there are cylinders. This permits the timer and distributor to be driven at the same speed so that they can be incorporated in one unit and driven by the same shaft. This arrangement is called a timer-distributor and the rotor of the distributor is superimposed on the timer cam so that it fits only in one position and the distributor housing is keyed to the timer housing. This construction assures the proper relation of timer and distributor but it must be borne in mind that **there is no electrical connection between them.**

When a carbon brush distributor is used the brush is always in contact with the inner surfaces of the distributor, part of which is insulating material between the segments. This continual rubbing of the carbon brush over the surface often causes a carbon deposit to be formed which short circuits the segments allowing

Fig. 131 — Raised segment distributor

the current to flow to the spark plug in the cylinder which offers the least resistance. This will cause misfiring of the engine.

Figure 131 shows a distributor having metal segments raised above the insulation and employing a metal brush. This design eliminates short circuiting of the segments.

Figure 132 shows a distributor placed in the secondary circuit and connected to the spark plugs. This completes the wiring of a typical battery ignition system for a four-cylinder engine.

Spark Plugs. — On high tension ignition systems it is necessary to have some device in each cylinder to maintain a gap of definite size across which the secondary current must jump to complete its circuit. This device is known as a spark plug.

Figure 133 shows a typical spark plug in cross-section. The central electrode should be made of some material which will not

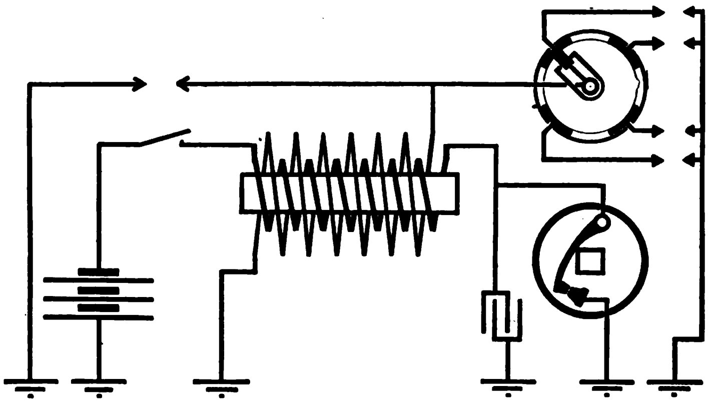


Fig. 132 — Wiring of battery ignition system

pit easily from the heat of the spark, such as chrome nickel-steel. This is insulated from ground by insulating material which may be composed of porcelain, mica, or steatite. The insulator must perform three functions: First, it must have sufficient dielectric efficiency to insulate the central electrode from the ground; second, it must present a surface in the combustion chamber to which carbon will not readily adhere; third, it must not crack under the intense heat in the cylinder. Insulators are finished with a highly polished surface which should not under any circumstances be scraped as this would permit carbon to adhere to the surface. Some plugs are made so that the insulators can be removed for replacement, inspection, or cleaning (Figure 134).

Fig. 133— Cross-section of spark plug

This necessitates a gas-tight joint between the insulator and shell which is usually obtained by screwing a bushing down against a gasket. When porcelain insulators are used there must be enough "give" at this point to allow for expansion of the insulator or it will be cracked. The body of the plug is usually made of steel, the lower part of which

is threaded to fit the thread in the cylinder. These threads are made up in three sizes: the $\frac{1}{2}$ inch with tapered pipe thread; the $\frac{7}{8}$ inch S. A. E. standard, with straight thread; the 18 mm. metric, with straight thread. On the $\frac{7}{8}$ inch and metric plugs a shoulder is provided the purpose of which is to tighten down on a gasket when the plug is screwed into the cylinder. This is not necessary with a $\frac{1}{2}$ inch plug because of the tapered thread which becomes gas-tight as it is screwed into the cylinder. Attached to the body of the plug is a small electrode which governs the size of the spark gap. By bending this electrode toward or away from the central electrode the size of the gap is regulated to give the best results. For battery ignition this gap should be between $\frac{1}{50}$ and $\frac{1}{32}$ of an inch for magneto ignition between $\frac{1}{64}$ and $\frac{1}{50}$ of an inch.

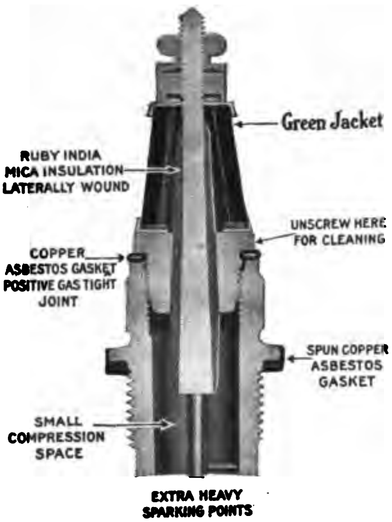


Fig. 134—Plug with removable insulator

The results obtained from an engine are largely dependent upon the location of the spark plugs. When two independent ignition systems are used, that is, battery ignition for starting and magneto ignition for running, using two separate spark plugs, the one that is nearest the inlet valve should be con- of plugs for this type of ignition system. The usual installation of plugs for this type of ignition is to place one directly over the inlet valve and the other over the exhaust valve. As the best mixtures will be nearest the inlet valve the system which should be used for continuous running should be wired to these plugs, while the other should be wired to the system used for starting.

Figure 135A shows a spark plug properly installed in a recessed spark plug cap. It can be seen that the electrodes project slightly into the combustion chamber and the best results are obtained under these conditions.

Figure 135B shows a standard plug installed in an unrecessed spark plug cap. It is seen that the electrodes of the plug do not extend into the combustion chamber and a pocket is formed. After a charge has been fired and the piston comes up on the exhaust

stroke it will compress burned gases in this pocket. Therefore, on the following compression stroke some of the fresh mixture will be compressed in this pocket where it will mix with the pocketed exhaust gas causing a very poor mixture. The mixture is so poor in some cases that it will not ignite and causes misfiring of the engine.

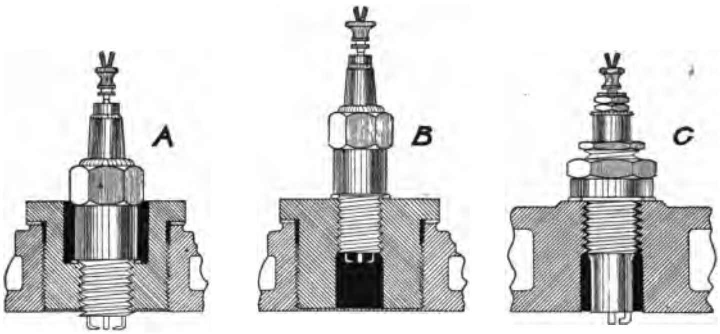


Fig. 135 — Spark plug locations

If the charge does ignite the rate of flame propagation will be reduced causing a loss of power.

Figure 135C shows a spark plug passing directly through the water-jacket without a recessed spark plug cap being used.

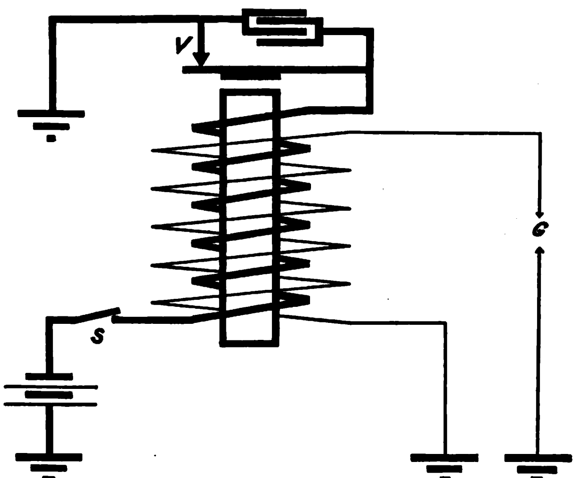


Fig. 136 — Vibrating induction coil

Although the electrodes project into the combustion space this installation is not entirely satisfactory because it is necessary to have a special design of plug for each engine. Many times it is impossible to obtain exact lengths of plug necessary to bring the

electrodes flush with the cylinder walls. This makes it imperative to use either spark plug caps that will take standardized plugs or else use a special plug designed for that particular engine.

If a second winding of a great many turns of fine wire is wound on a simple vibrator coil such as shown in Fig. 124 a spark coil is obtained. Figure 136 shows such a coil, one end of the secondary being grounded while the other is led to a spark gap *G*, the other side of which is grounded. When the switch *S* is closed the vibrator *V* rapidly makes and breaks the primary circuit as already explained. This causes a magnetic field to be alternately built up and broken down inducing a current of high voltage in the secondary which can jump the spark gap to the ground.

If this spark gap is inside the cylinder of an engine the explosive mixture will be fired when the switch *S* is closed which will cause a spark to jump the gap. In this way the spark coil is used for ignition purposes. It was applied to early ignition systems and still may be found on a few machines.

Figure 137 shows a four-unit coil system in which four separate spark coils are used. One side of the battery *B* (or other source of current) is grounded while the other is connected to the primary windings of the coils *C, D, E,* and *F*. The other ends of the primaries are connected through the vibrators *V* to the contact segments of a revolving switch *S* sometimes called a "commutator." Across each of the vibrators is connected a condenser *K*. The rotor *R* of the switch *S* is positively driven by the engine and is connected to ground, successively completing the circuits through the contact segments. Since there are as many segments as there are cylinders it must be driven at half engine speed. One end of each secondary is connected to its primary through which it is grounded, while the other end is wired to a particular spark plug depending upon the firing order of the engine. When the revolving rotor touches one of the contacts, current from the battery flows through the coil connected to it, causing its vibrator rapidly to make and break the primary circuit. This induces high voltage impulses of current in the secondary and sparks jump the gap at the spark plug to which the secondary is connected. This is identical with the Ford system in which the current is supplied by a low tension magneto instead of a battery.

This system eliminates the necessity for a distributor but makes four separate spark coils necessary, each with a vibrator to be kept in adjustment and contacts to clean. It is practically impossible to adjust all the vibrators so that the spring tension is the

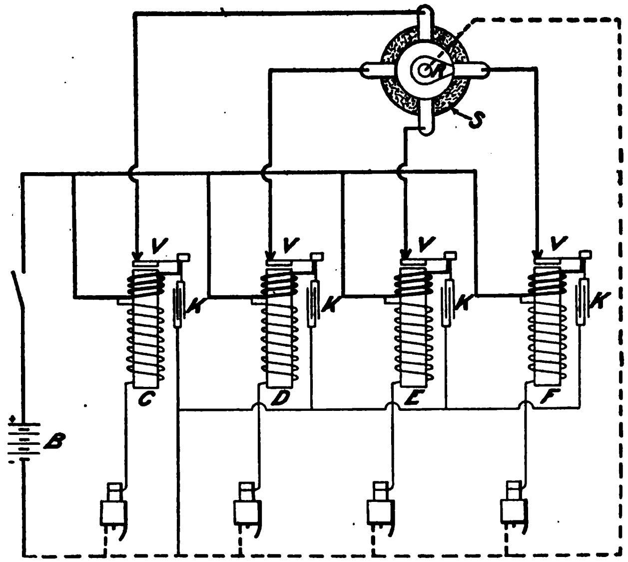


Fig. 137—Four-unit coil ignition system

same on each. This causes the sparks in the different cylinders to vary in intensity and uneven running of the engine results.

To remedy this difficulty a **Master Vibrator** may be installed in

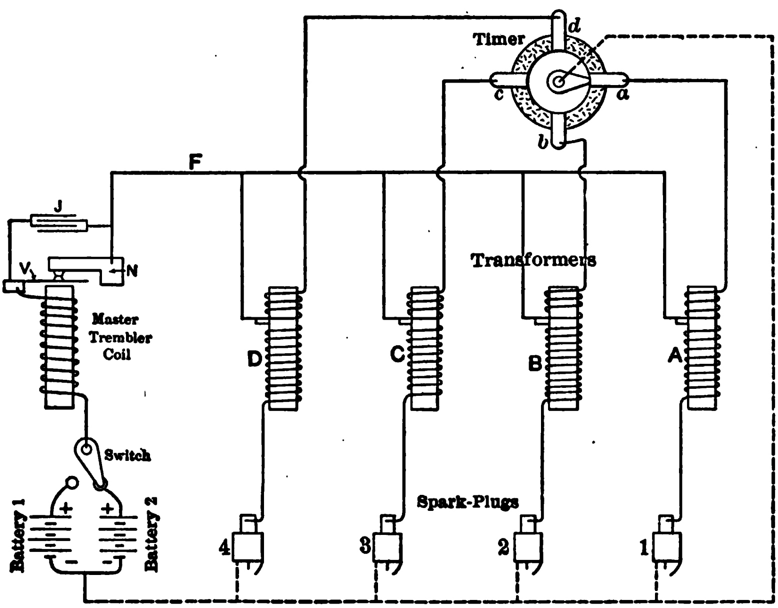


Fig. 137a — Four-unit coil system with master vibrator

the system. This consists of a vibrating coil having but one winding which is connected in the primary circuit as shown in Fig. 137a. All the spark coils are non-vibrating or if vibrating coils are installed the contact screws should be screwed down so they hold the springs tight against the iron cores of the coils.

When the rotary switch *S* touches one of the contacts, current flows from the battery *A* through the master vibrator *M* and coil *A, B, C,* or *D,* depending upon which contact is touched. The vibrator *V* makes and breaks the primary circuit, inducing current in the secondary winding of the spark coil just as when it had its own vibrator. This makes it possible to get the same intensity of spark in all the cylinders with one vibrator to adjust.

Bosch Battery Ignition

This ignition consists of two self-contained units. The coil and timer-distributor, with or without automatic advance.

The coil (Fig. 138) is wound for use with either six or twelve volts. When used with six volts or twelve volts it employs a resistance in the primary circuit. The resistance in each case is

Fig. 138—Bosch coil

different. The object of the resistance is as a ballast for protection to the winding and to prevent the burning of same.

This coil is composed of five main units: The housing, carrying a high tension terminal, arranged so that it can be moved to any desired position. The two end caps made of insulating material. The resistance, which is fine wire wound on porcelain to prevent burning in case of overheating. The winding, which is encased in an iron shell.

When the parts are assembled with the main holding bolts, the coil is dust-proof and weather-proof. Both ends of the primary winding are connected to studs, which pass through end caps and are

used as the primary terminals of the coil. One end of the secondary is connected to the ground side of the primary winding, and the other end is connected to the iron shelf around the winding. The terminal on the coil case employs a spring, which presses against the iron shell, and, therefore, can be turned to any position. The features of this coil is its operation on very low voltages, its low time interval for saturation, and its simplicity.

Fig. 139 — Bosch timer-distributor

The timer-distributor (Fig. 139) is for manual control. It employs many new features. It is of the construction used with the saturated coil, one contact being grounded and the other insulated from the ground and brought out to an insulated terminal. The condenser is mounted in the timer, connected between the interrupter points, and is encased in a moisture-proof metal container. All these parts are contained in a cup, which is removable as shown in Fig. 140. This makes it very accessible for cleaning the parts, as the cup can be removed without changing the timing or removing the housing from the engine.

The distributor is superimposed upon the timer and is of the jump spark type. The rotor is driven by the same shaft as the

Fig. 140—Bosch timer

timer cam. The distributor employs a special type of plunger terminal. This makes a positive connection and the cable is easily

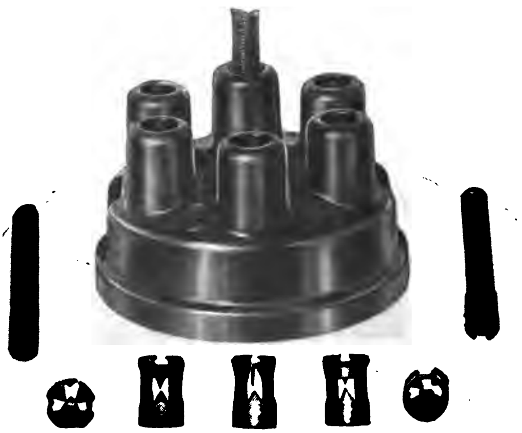


Fig. 141 — Bosch distributor

disconnected. By this method of attachment there is less possibility of short circuits. The connections are made by cutting the

cable flush and not stripping the insulation and then by pushing same into the terminal towers (Fig. 141).

With the automatic type of timer the same main parts are used except for a larger housing and the same features are employed. This type of timer also employs a manual control as well as the automatic. The manual advance is accomplished in the usual manner by moving the housing, which carries the timer contacts and distributor. The automatic advance is of a new construction employing a ring type of governor (Figs. 142 and 143).

Fig. 142 — Bosch governor

Fig. 143 — Bosch governor

This governor is designed especially for each engine as the curve of advance is different in accordance with the engine's requirements. This is accomplished in four ways:

First, by the movement of the governor. If a heavy spring is used of course it will operate slower and give less movement for a given R. P. M. of the engine than if a lighter spring is used, thereby a series of curves of movement of the governor can be made to fit any practical condition.

Second, by setting the initial tension of the spring; in this way the movement can be started at any desired R. P. M. of the engine. As many engines do not require advance for the first few hundred R. P. M. this can be adjusted to suit the particular case.

Third, by limiting the movement of the crank operating the advance; this crank is attached to the ring type governor. Some engines require rapid advance and then the same amount of advance for all higher R. P. M. Some require a more gradual advance and do not require advance at lower speeds of the engine. This is arranged by adjusting a set of screws placed under the crank arm. This can be adjusted in accordance with the exact conditions required, stopping the operation of the governor at any desired speed.

Fourth, by the use of different center distances on the crank arm. If the distance is increased between the points of movement by the governor and the pin operating the advance cam, the greater will be the amount of advance for any given movement of the governor and *vice versa*. This feature permits any amount of advance to be obtained for any given R. P. M. By the combination of these four principles any desired curve can be obtained.

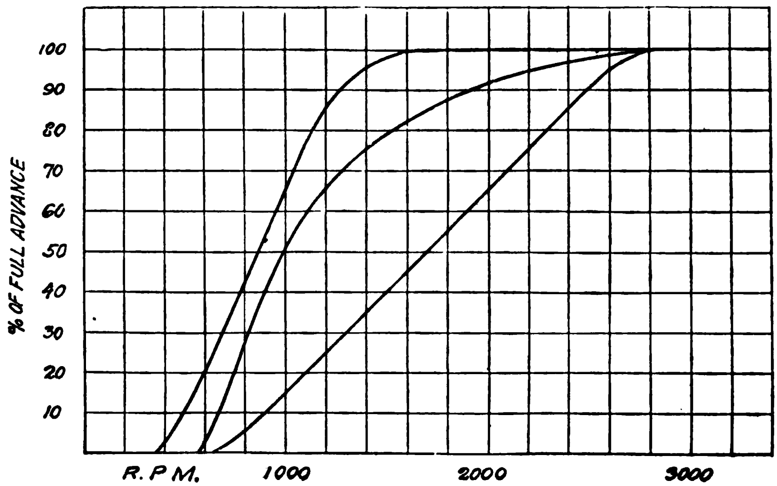


Fig. 144 — Curves of timing

Figure 144 shows three of the possible curves that can be obtained; there is no limit to the amount of curves which can be arranged.

The wiring of this system is the same as the usual grounded type of battery ignition system. One of the primary leads of the coil is connected to the timer; the other side of the primary is connected

to the switch which in turn connects the battery. The secondary of the coil is connected to the center terminal of the distributor. The spark plugs are connected in the usual manner.

North East Ignition System

The complete ignition system consists essentially of three self-contained units; the single unit coil, the timer and distributor

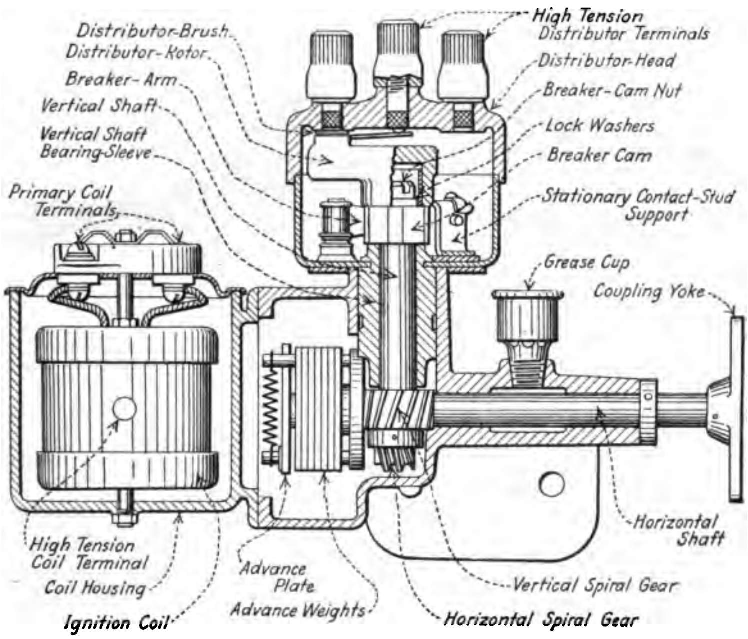


Fig. 145 — North East Ignition System

assembly, and the automatic advance. Each of these three units is constructed so as to be easily removed for repairs and replacement (Fig. 145).

The coil is constructed to operate on 12 volts. It differs from the ordinary coil in having **both** ends of the primary brought out to terminals on the coil housing. As usual, one end of the secondary is grounded while the other is connected to a stud on the side of the coil and this stud is connected to an insulated binding post on the side of the coil housing. Around this post is a raised section of the housing designed to act as a safety spark gap. If at any time the resistance between this post and the ground at the spark plug becomes greater than that of this air gap the current will jump from the post to the housing, relieving the pressure in coil so that the

insulation will not be broken down. When sparking occurs at this point it is usually an indication of a broken or disconnected cable or too wide a gap at the spark plug.

The timer (Fig. 146) is typical of the construction used for saturated coils. Both contacts of this timer are insulated from the ground and the condenser is wired in parallel with the contact points

Fig. 146 — Timer with condenser

and contained in the timer housing. This makes the condenser accessible and easy to replace, but it must be remembered that the condenser must be of a certain capacity which is determined by the coil. Therefore, when replacing a condenser one designed for this coil must be used.

The distributor is of the flush segment type using a metal brush. The rotor is superimposed upon the timer cam both being driven by the same vertical shaft.

Fig. 147 — Automatic spark advance

There are two methods for advancing and retarding the spark on this system. The manual control moves the housing carrying the contact points, this movement being limited so that further advance must be accomplished by the automatic device. The automatic control (Fig. 147) is operated by centrifugal action so that as the speed increases, the shaft operating the timer cam is advanced with respect to the operation of the engine, the reverse taking place as the speed is diminished. Since the timing of the

ignition is partially dependent upon the speed of the engine this dual control proves very satisfactory.

Figure 148 is a wiring diagram showing the internal wiring of this system as applied to the Dodge car and Fig. 149 shows the actual external connections. One end of the primary is connected to the ignition switch while the other end is connected to one of the timer terminals. The switch is arranged so there are two " on " and two " off " positions. In one " on " position the current passes through the primary of the coil, then through the timer and back to the switch where it is grounded. In the other " on " position the current passes through the timer and then through the primary winding in the opposite direction returning to the switch where it is grounded. The object of a switch of this kind is to cause the current to pass through the primary in the opposite direction each time the switch is turned to the " on " position. If the current flows through a primary each time in the same direction the soft iron

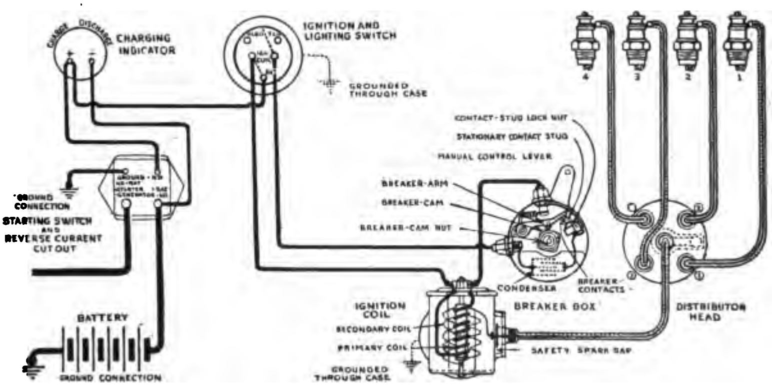


Fig. 148 — Internal wiring diagram

core will retain some of its magnetism after the circuit is broken. This prevents a complete breaking down of the magnetic field and will lower the self and mutually induced voltage. This is prevented by building up the field each time in the opposite direction.

Delco Ignition System

There are many constructions of the Delco battery ignition system, but they are essentially the same in operation regardless of their particular design.

The single spark ignition system is made up of two self-contained units, the coil assembly and timer-distributor assembly with auto-

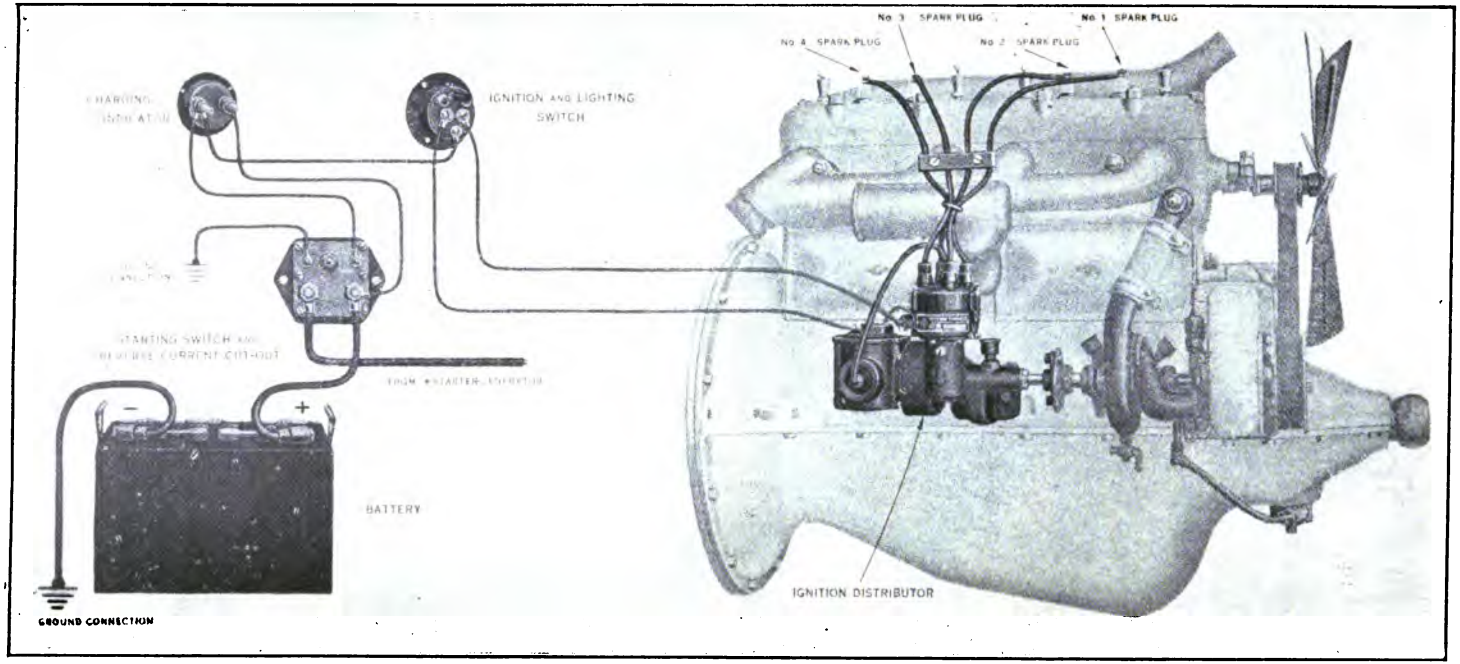


Fig. 149 — External wiring, North East

matic advance. The coil housing is arranged so that it can be mounted on the dash board or can be easily attached to the timer as shown in Fig. 150.

The coil is wound for use with either six- or twelve-volt system, a resistance being connected in the primary circuit. These resistances act as a ballast coil for the amount of current flowing into the primary winding and as a protection to the coil.

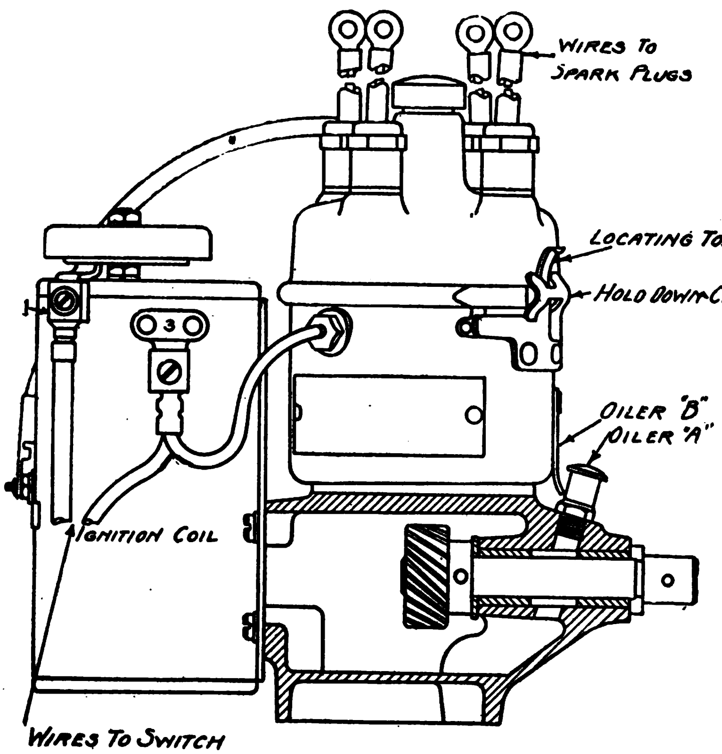


Fig. 150 — Unit assembly

There are four terminals in the coil housing. The ends of the primary winding are connected to two of these, one side of the condenser is connected to the third, and the ungrounded end of the secondary is connected to the fourth.

The condenser is contained in the coil housing and connected in the parallel with the interrupter points. In some constructions of coils the condenser is left out and placed in the time-distributor housing.

The timer is of the construction used with a saturated coil. Both contacts are insulated from the ground. The distributor is super-

imposed upon the timer and is of the flush segment type, the rotor being driven by the same shaft as the timer cam.

This system has both manual and automatic spark advance. The manual advance is accomplished in the usual manner by moving the housing carrying the contact points. The automatic advance is of the usual centrifugal construction advancing the cam with relation to the operation of the engine, the amount of the advance being controlled by the speed of the engine.

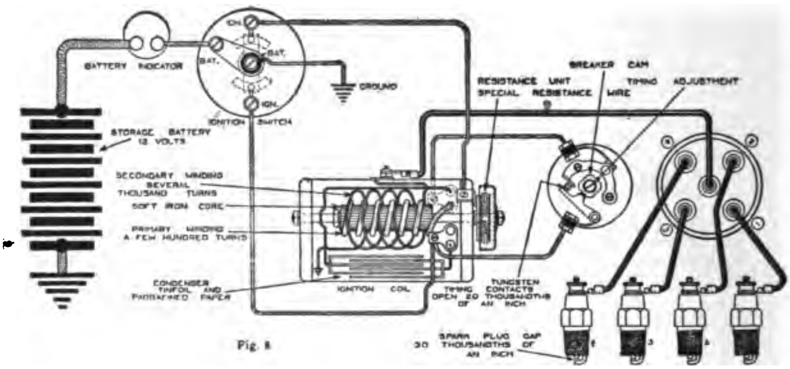


Fig. 151 — Internal wiring diagram

Figure 151 is a wiring diagram showing the internal wiring of this system as applied to the Dodge car and Fig. 152 shows the actual external connections. One side of the battery is grounded and the other side is connected to the ignition switch passing to the starting switch and through the ammeter. From this point the current will flow through the ignition system in two ways and is governed by the position of the switch when in the " on " position. The switch is so arranged that it causes the current to flow first in one direction and, in the other " on " position, in the opposite direction. One path is as follows: The current flows to the coil passing through the resistance and then through the primary winding, the other end of the primary winding being connected to the timer. From the timer the current flows back to a terminal on the coil housing, this being connected to one side of the condenser the other side of which is connected to the end of the primary leading to the timer. From this binding post the current is led back to the switch where it is grounded. When the switch is turned " off " and then " on " again the current takes the same path but flows in the opposite direction. This is accomplished by the switch for in one position the lead from the coil is connected to the battery terminal and the lead from the timer is grounded. In the other position of the switch these connections are reversed.

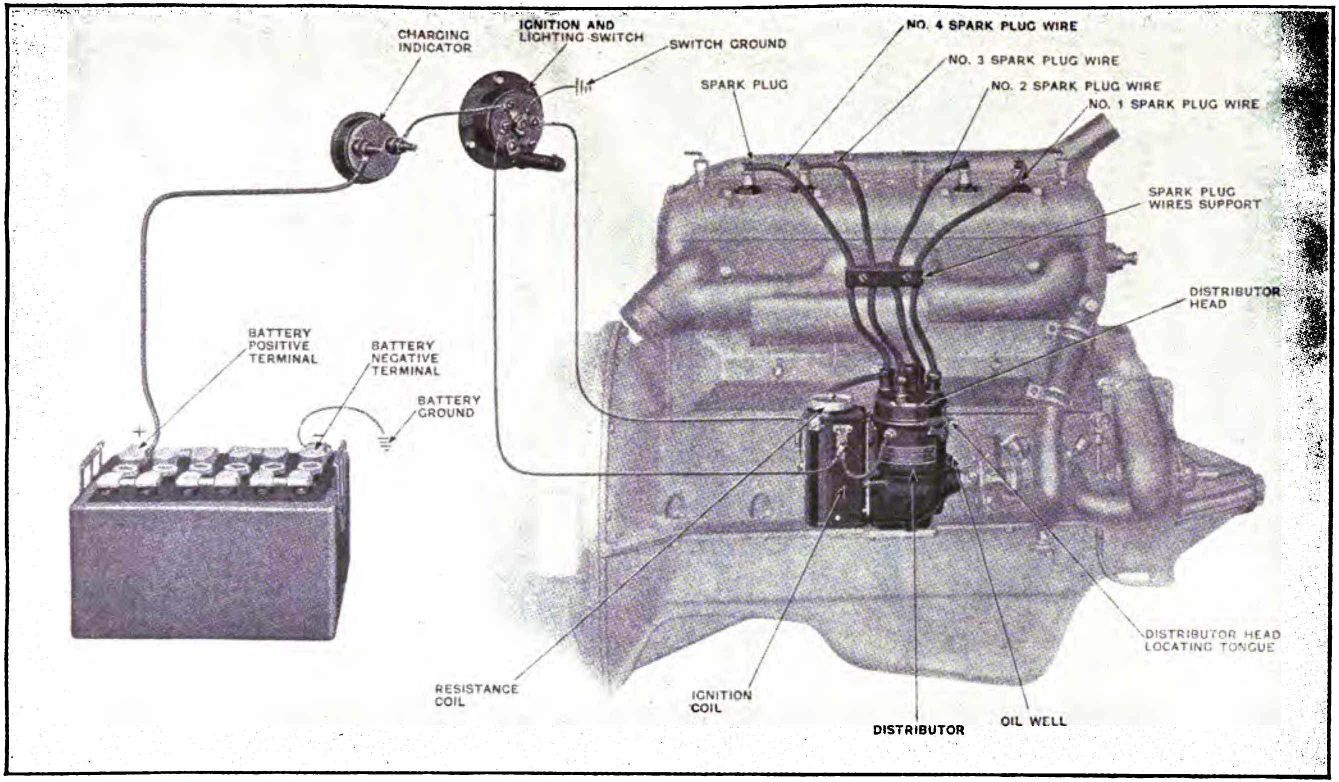


Fig. 152 — External wiring Delco

As the current passes through the primary of the coil in a different direction every time the engine is operated it eliminates the possibility of the soft iron core becoming magnetized thus weakening the strength of the induced currrent. It also prevents excessive wear on one of the contact points.

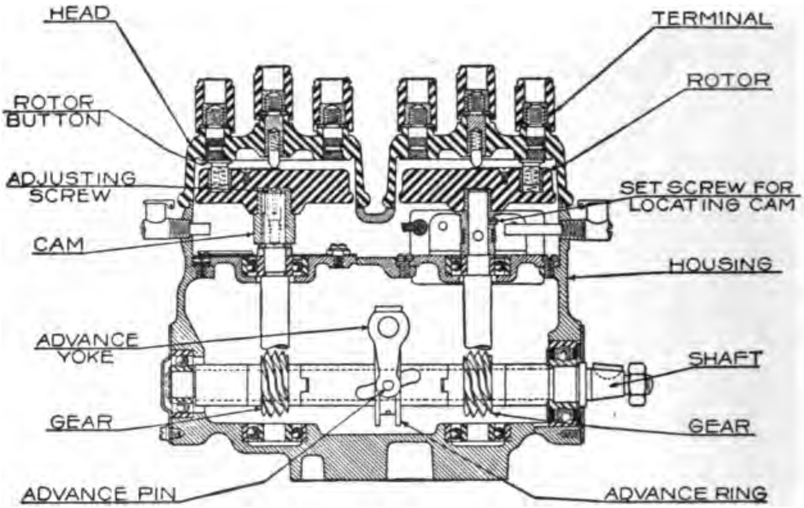


Fig. 153 — Delco two-spark timer

In the two-spark construction as shown in Fig. 153, there is one shaft operating both of the distributors. Instead of having two distinct and separate interrupter mechanisms, it is all contained in

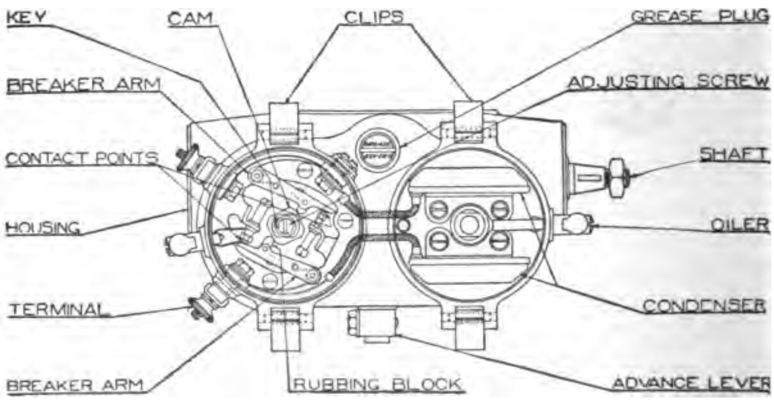


Fig. 154 — Delco two-spark timer

one housing as shown in Fig. 154. There are two sets of interrupter points entirely seperate in their electrical connections but

operated by the same cam. The condensers are contained in the housing, which would normally be used for one of the interrupter mechanisms. Two separate coils are used with this system and the connections are the same as with any of the other Delco Battery Ignition sets. With this construction it is possible to attain two sparks in the cylinder simultaneously instead of the one spark as normally used.

This system is used extensively for racing purposes and in certain construction of motors, where it is advantageous to increase the rate of flame propagation.

ATWATER KENT

Fig. 155 — Atwater-Kent coil

This system consists of two separate self-contained units, the coil assembly and timer-distributor assembly, with or without automatic advance.

The coil (Fig. 155) is a new construction and consists of the winding contained in an insulated housing with the resistance coil located at the top. The connection in the center is the high tension terminal connected to one end of the secondary. The very top of the coil is connected to one end of the resistance, the other end of which is connected to the primary. Directly below the resistance is a cable attached to the other end of the primary.

Fig. 156 — Atwater-Kent timer

The timer (Fig. 156) is constructed for the saturated type of coil and has the condenser mounted in the housing, which is directly connected between the interrupter points. The rotor is superimposed on the timer cam and the distributor mounted on top of the timer housing.

The distributor (Fig. 157) is of the jump spark type. Both manual and automatic spark advance are employed in this system, each being independent of the other. The manual control moves the housing carrying the contact points, as well as the dis-

tributor. The automatic advance is of the centrifugal construction (Fig. 158), advancing the position of the cam with respect to the rotation of the shaft as the speed increases.

Figure 159 shows the internal connections of this system. One side of the battery is connected to the ground and the other side is connected to the ignition switch. The switch is connected to the

Fig. 157 — Atwater-Kent distributor

resistance, the terminal of which is at the top of the coil. This resistance is in turn connected with the primary winding of the coil. The other end of the primary is connected to the terminal on the timer which connects with the condenser and insulated interrupter point. The other side of the condenser is grounded as well

Fig. 158 — Automatic advance mechanism

as the other interrupter points. One end of the secondary is connected to the primary through which it obtains its ground; the other end is connected to the center terminal of the distributor. The other terminals of the distributor are connected to the spark plugs in accordance with the firing order of the engine.

Atwater-Kent ignition systems also employ, in certain other timers, what is known as the Uni-Spark Construction of interrupter. This construction shown in Fig. 160 is for use with a non-saturated type of ignition system.

The purpose of this mechanism is to make the circuit and break it again immediately so that the battery current will flow for a very short period of time thereby reducing current consumption to a minimum and to give the same length of contact of the interrupter points at all engine speeds, which insures a uniform spark.

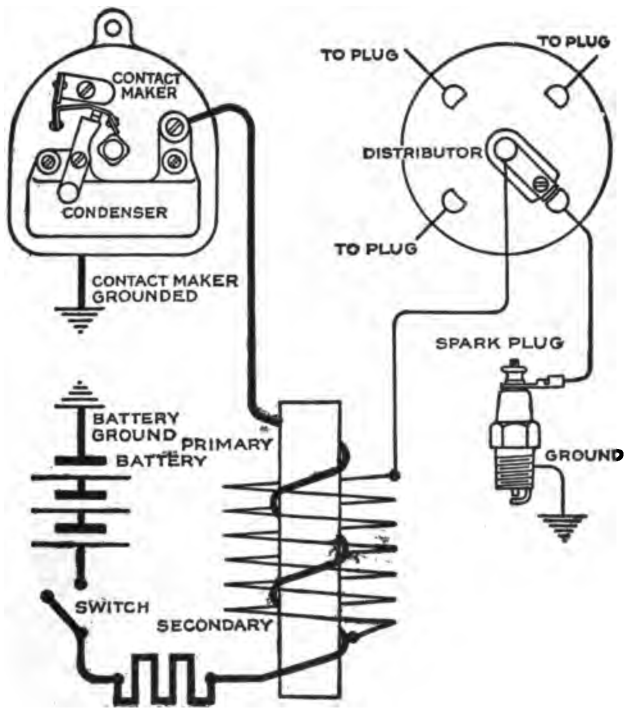


Fig. 159 — Wiring Atwater-Kent

The *notched shaft* is driven at half crank shaft speed and has as many notches as there are cylinders to the engine. As the *notched shaft* revolves it engages the *lifter* and draws it in the direction of its length against the tension of the *lifter spring* until its hooked end is back of the *latch*. In this position it becomes unhooked from the *notched shaft* and as the spring returns it to its original position it strikes the *latch* which swings against the movable *contact spring* forcing the contact points together. This stops the movement of the straight blade of the *contact spring* but the curved blade continues to travel and its hook leaves the end of the straight blade.

When it has reached the limit of its motion it springs back striking the straight blade a sharp blow, which causes a very sudden separating of the interrupter points. In this device three important features are obtained; current flowing through the coil for a very short period, current flowing for the same length of time regardless of engine speed and a very quick opening of the primary circuit. Adjustment is made by removing one or more of the thin washers found under the head of the *contact screw.*

The operation of the other units of this system is essentially the same as in other systems.

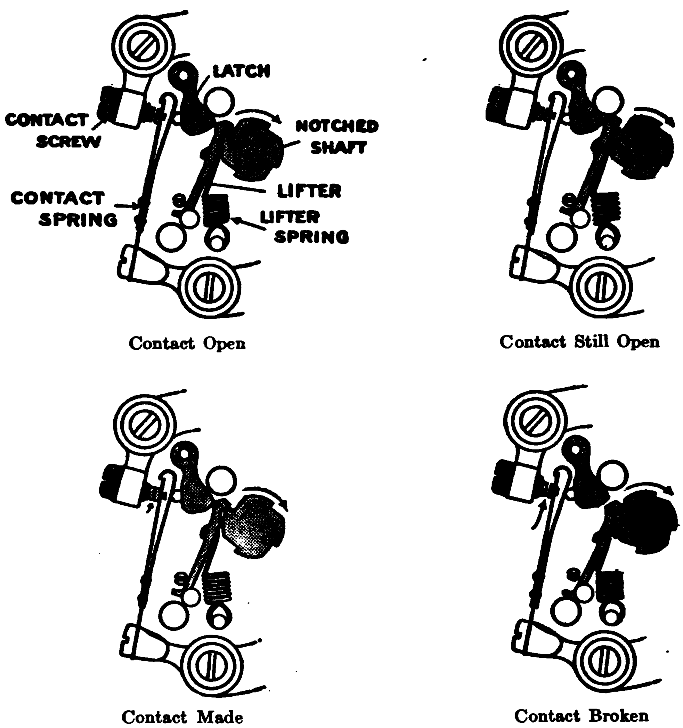


Fig. 160 — Uni-Spark timer

Remy Ignition System

This system consists of two units mounted on one bracket, the coil assembly and the timer-distributor assembly. Both ends of the primary winding are led to binding posts on the top of the coil housing, one of these being connected to the battery and the other to the timer. One end of the secondary is internally grounded the other being led out to a binding post on the side

of coil housing. The condenser is contained in the timer housing, one side being grounded and the other connected to the primary wire at the timer. This coil may or may not be equipped with a resistance to reduce the amount of current flowing through the primary.

The timer is of the construction used for saturated coils. Only one of the contacts is insulated the other being internally grounded.

The distributor is of the raised segment type with a metal contact segment on the rotor. It is superimposed on the timer cam and is driven by the same shaft. Advanced and retarded ignition are accomplished by manual control in the usual manner by turning the timer-distributor housing.

This is a typical one-wire system using a ground return. Figure 161 shows a wiring diagram of the internal connections.

Practically all makes of Battery Ignition Systems of the non-vibrating type are like one of those just described. The saturated coil is nearly always used and the reverse current switch is quite common. The tendency now seems to be toward placing the condenser in the timer housing rather than placing it inside the coil housing where it is hard to get at. The combined timer-distributor is used almost without exception and a compact unit with short

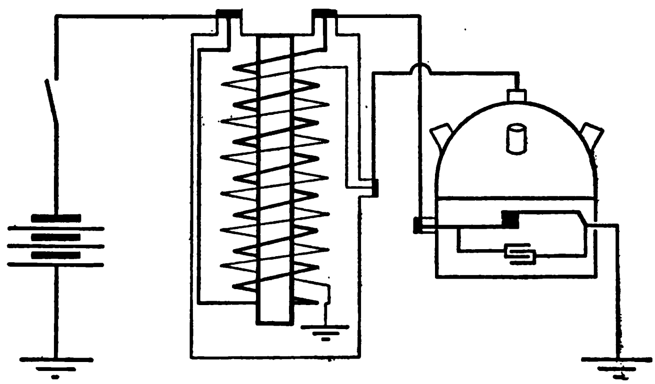


Fig. 161 — Internal wiring diagram

direct connections is the predominating construction. The recent wide adoption of battery ignition systems has resulted in many improvements and excellent results are obtained.

CHAPTER XVII

MAGNETOS

Armature Type

Before electrical generators were used on motor vehicles a great deal of trouble was experienced with battery ignition systems since the source of current was not always dependable. If the battery was composed of dry cells it was affected by dampness and was short-lived. If a storage battery was used the machine was put out of operation every time it became necessary to recharge the battery. This resulted in constant trouble and annoyance.

To eliminate this unreliability the magneto was developed and the high tension magneto has been adopted for ignition, since it is more reliable, being a self-contained unit. The efficiency of operation of the battery ignition system depends upon the current flowing through the primary winding and the rapidity of collapse of the field. Difficulties are encountered due to additional resistance in the primary circuit or the reduction of the battery voltage. These difficulties are not experienced with the magneto as all connections are internally made and an outside source of current is not depended upon to magnetize the core.

The iron core of the spark coil is magnetized by current by some outside source such as a battery. The magneto eliminates this, the armature core becoming magnetized by being placed between the opposite poles of strong permanent magnets so that it forms a part of a compound magnetic circuit. The amature core is of the so-called "shuttle" or "anchor" type and is mounted upon a horizontal axis so that it can be revolved between the pole shoes of the permanent horseshoe magnets (Fig. 162). It is so shaped that wire may be wound upon it. The air gaps across which the magnetic lines of force must flow are made as short as possible. The bearings upon which the armature shaft is mounted must be in

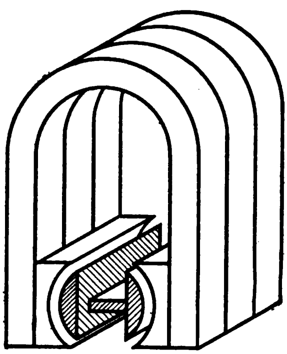


Fig. 162 — Armature in place between magnets

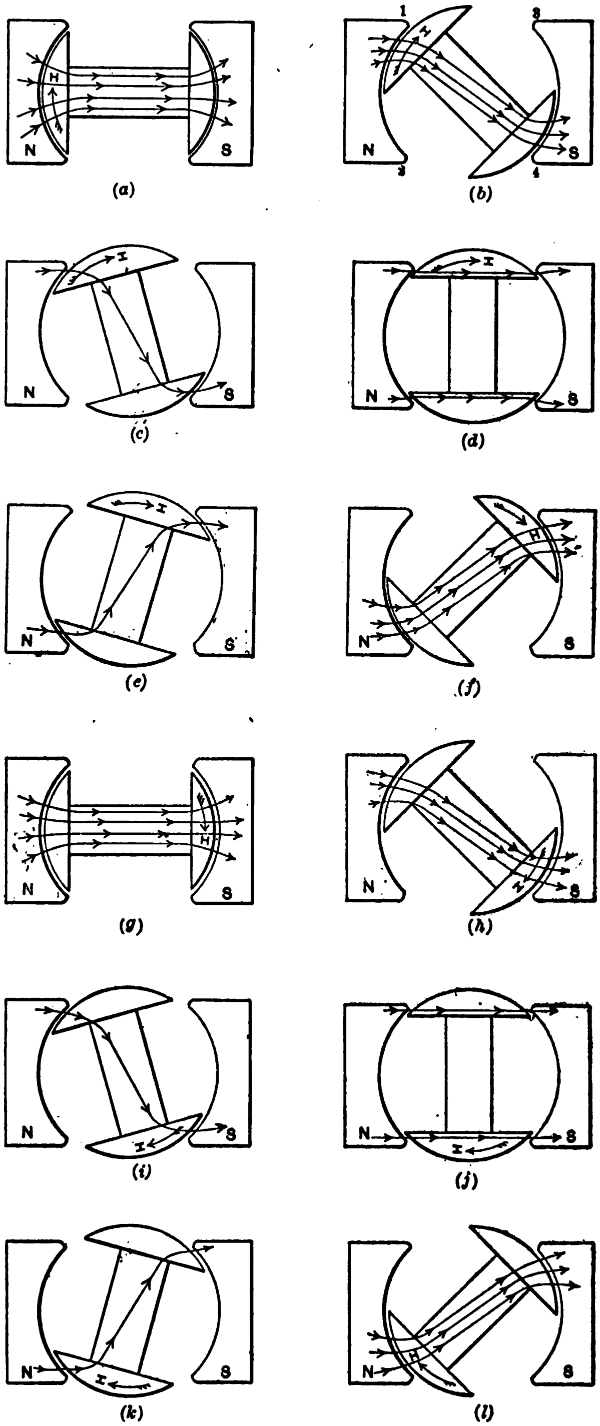


Fig. 163 — Change of magnetic flux in revolving armature

good condition since proper results will not be obtained if the armature core is allowed to rub either of the pole shoes.

Figure 163 shows several positions of the armature core of a magneto with relation to the pole shoes during one revolution. Starting with the armature core at position *A* all the lines of force flow in at *H* and through the core neck in passing from the north to the south poles of the horseshoe magnets. If the core is revolved clockwise as indicated by the arrow, it will next reach the position *B* and fewer lines of magnetic force will flow through the core neck since less of the curved sides of the core are now opposite the pole pieces. When the core has revolved to position *C* still less of the curved portion is opposite the pole pieces and the number of lines of force passing through the core neck is still further decreased. When the core has reached vertical position *D* all the lines of force flow through the curved sides and none through the neck of the armature core. The reason for this is because the magnetic lines of force take the path offering the least resistance. As the armature core is revolved to position *E* a few lines of force start to flow through the core neck again but in the opposite direction leaving it at *H*. As the armature core is revolved through the position *F* the number of lines of force flowing through the core neck increases until it reaches a maximum when the core is revolved to the position *G*. During the next half revolution as the armature revolves through positions *H* to *L* exactly the same changes of magnetic flux take place through the core neck as during the first half revolution.

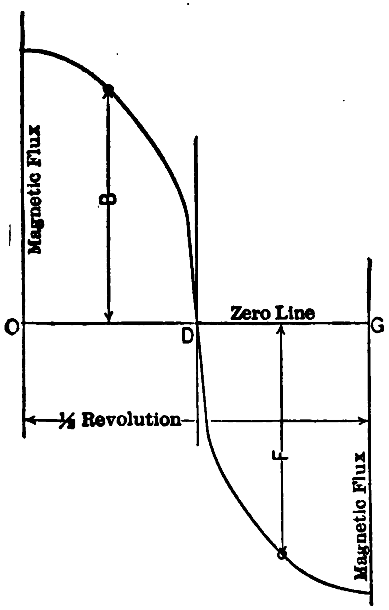


Fig. 164 — Curve showing flux variations during one half revolution

When the armature core is rotated at a uniform speed the magnetic flux flowing through the core neck changes from a maximum at *A* to zero at *D*, to a maximum in the reversed direction at *G*, and to zero at *J* or from a maximum to zero twice during one revolution. The rate of change is not uniform and is greatest as the armature core approaches the vertical position. This is shown graphically in Fig. 164.

If a primary and secondary

winding is wound on a soft iron ring (Fig. 165) and the amount of current flowing through the primary is varied the magnetic flux flowing around the iron ring will be varied accordingly. When the number of lines of magnetic force threading through the secondary is changed a current will be induced in it. The more rapid the rate of change the greater will be the induced voltage. This electrical principle of induction is expressed in Faraday's Law and is stated as follows: "The induced E. M. F. is proportional to the rate of change of the magnetic lines of force or flux threading through a coil." This principle is employed in the operation of a magneto since the magneto flux flowing through the armature core, about which the conductors are wound, varies in intensity.

Fig. 165 — Ring transformer

If a coil of insulated wire is now wound about the armature core neck (Fig. 163) to form a complete circuit, current will be induced in the winding when the armature is revolved between the pole pieces. This is due to the change in magnetic flux through the armature core. The induced voltage will be proportional, or nearly so, to the rate of change of the magnetic flux through it. In Fig. 166 a complete electric circuit is obtained by grounding both ends of the insulated wire to the core. These connections are indicated by black spots *1* and *2*.

When the armature is at *A* (Fig. 166) it is in one of the positions where the flux is a maximum through the armature core neck. As the armature revolves through the first quarter revolution from position *A* to *D* the magnetic flux through the core neck decreases, slowly at first but at an increasing rate until position *D* is reached. The decrease of magnetic flux through the core neck causes an induced electric current to flow as indicated through the insulated wire of the winding. The path of the current is from *2* through the insulated wire to *1* and thence through the metal of the core from *1* to *2*. The current flow beginning at zero keeps increasing during the first quarter revolution and reaches its maximum at position *D* of the armature. As the armature is revolved from position *D* the current decreases in value until it drops to zero again when the armature has reached position *G*. During the second half revolution from *G* to *L* similar variations in the current take place but the current now flows from *1* toward *2* since the direction of the magnetic flux through the core neck has been reversed.

Starting from position *A* the current increases from zero to a

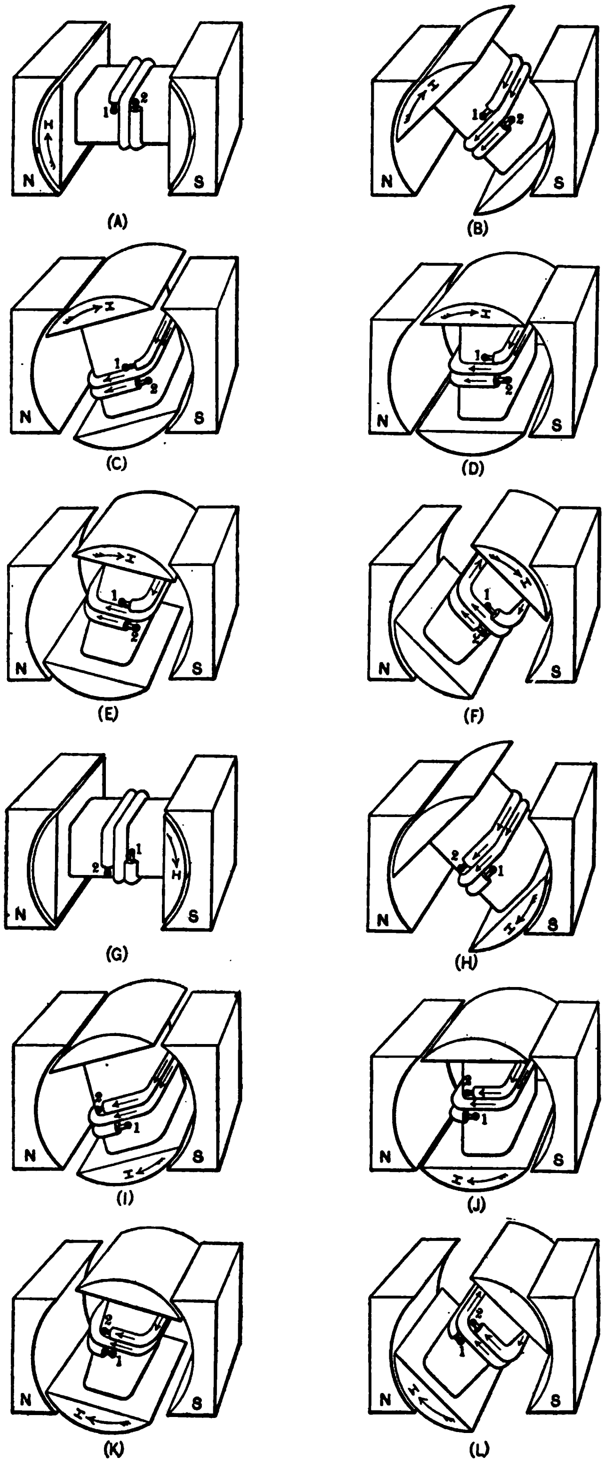


Fig. 166 — Electro-magnetic induction in primary circuit

maximum at D and back to zero again at G. It then increases in the opposite direction to a maximum at J and back to zero again at A. An electric current of the kind just described is called an alternating current.

The induced current in the primary winding depends upon the rate of change of flux through the armature core neck. If the speed of rotation of the armature is increased the rate of change will be proportionately increased. Therefore, the induced voltage depends upon the speed at which the magneto is driven.

In order to start an engine on magneto sufficient speed of rotation must be attained to produce current in the primary. If a powerful engine is cranked by hand, especially a heavy duty type such as is used on tractors, sufficient speed will not be attained to produce the desired current. This difficulty is overcome by the use of an impulse starting device (Fig. 167).

It is so designed that a catch holds the magneto armature (or rotor) during 80 degrees of travel and then is tripped throwing the

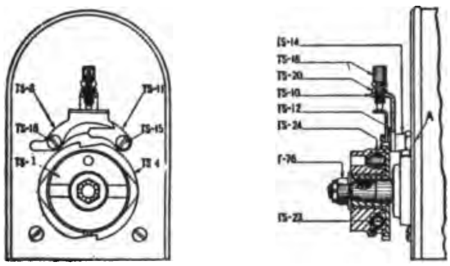


Fig. 167 — Impulse starter

armature ahead at the rate of approximately 500 R. P. M. by means of a coil spring, assuring a good spark properly timed with the engine. By pressing down on the back end of ratchet catch lock *TS–8,* ratchet catch *TS–11* will be released. This allows it to engage with the notch on ratchet *TS–4,* which is keyed to the armature, holding it stationary while case *TS–1* turns through 80 degrees compressing the coil spring *TS–23.* When the lug on case *TS–1* revolves far enough to lift catch *TS–11,* the armature is thrown ahead with a rush by the compressed spring. This produces the desired induced current even though the engine is being turned over slowly. The armature when released is thrown to position D (Fig. 163) so that it passes quickly through the point where the maximum rate of change of flux takes place. The same thing takes place during the second half-revolution of the armature.

When the armature is in positions A and G (Fig. 163) it accommodates itself to the greatest number of lines of force and, there-

fore, resists being turned from these positions. If a flexible shaft coupling is provided the armature will lag behind the shaft causing tension in the coupling. When the tension has become sufficient the armature will be forced to rotate. The stored-up energy then turns the armature with increasing speed causing it to catch up with the shaft. This results in the armature rotating through the vertical position at rate exceeding the speed of the shaft, thus increasing the induced voltage. For this reason flexible couplings are advantageous and often used.

The voltage induced in a single winding on a revolving armature core will not be sufficiently high (approximately 200 volts) to jump a fixed air gap and for this reason a magneto of such construction is called a low tension magneto. It is still necessary to send the current through a spark coil in order to obtain sufficient voltage for ignition purposes; hence, all the parts of the battery ignition system remain except the battery which has now been replaced by a low tension magneto. This arrangement will still be found in a few ignition systems used for motor-propelled vehicles.

High-voltage current can be obtained directly from the magneto by the addition of a secondary winding. This is wound on top of the primary winding on the armature core just as the secondary of a spark coil is wound on top of its primary winding. As the armature is revolved current is built up in the primary winding due to the rapid change of magnetic flux through the armature core. This current reaches a maximum when the armature has reached approximately a vertical position *D* or *J* (Fig. 166). During the same part of a revolution current is also induced in the secondary winding but the voltage is not sufficiently high to cause a spark to jump an air gap. If the primary circuit is suddenly broken as the armature moves just beyond these positions the magnetic field set up by the current flowing through the primary will be broken down. Just as in the spark coil this induces a current of high voltage in the secondary (approximately 5000 volts) which will jump a fixed air gap.

Since it is necessary for the primary circuit to be broken at certain definite positions of the armature an interrupter is used driven by the armature shaft. In this way the rotation of the armature and interrupter are kept perfectly synchronized.

Figure 168 shows all the necessary parts of a high tension magneto and diagrammatically illustrates how they should be connected. The interrupter on a magneto will normally have two cams since the primary circuit can ordinarily be broken but twice during one revolution. This is because there are but two positions of the arma-

ture in common constructions of magnetos at which the induced primary current is at a maximum.

A condenser is connected in parallel with the breaker points to prevent arcing and is generally mounted in the end of the armature revolving with it.

A switch is provided which will continuously ground the primary circuit when closed. This prevents the interrupter from interrupting

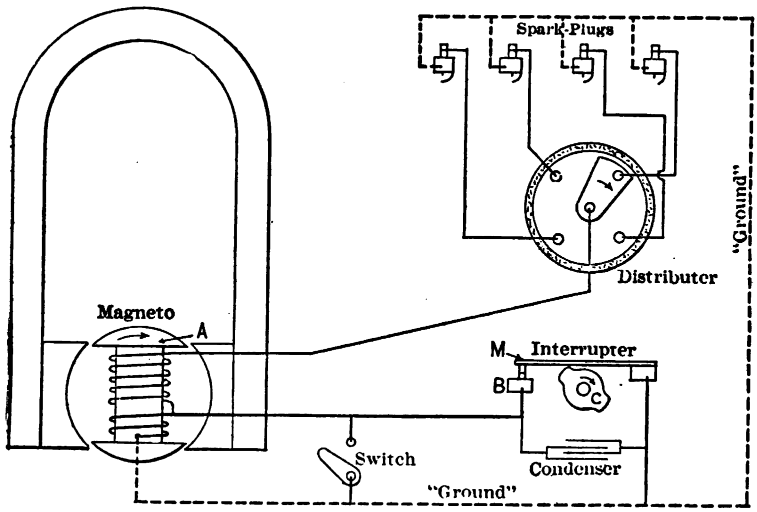


Fig. 168 — Typical wiring diagram of high tension magneto

the primary circuit consequently preventing a current of high voltage from being induced in the secondary. By closing the switch the ignition is " shut off."

One end of the secondary is grounded through the primary, while the other is connected to a distributor just as was done in a battery ignition system. The same types of distributors are found on magnetos as are used on battery ignition systems, there being as many contact segments as there are cylinders. For this reason the distributor will always be internally geared so as to run at one half engine speed (on four-cycle engines).

The ordinary construction of magneto with " shuttle " type of armature produces two sparks during each revolution equally spaced or 180 degrees apart. This is because there are but two points where the rate of change of magnetic flux through the armature is greatest.

When magneto ignition is used for twin-cylinder motorcycles with V-type cylinders a special construction is necessary

to obtain two sparks **not** equally spaced. This is required because the cylinders are set at an angle varying from 42 degrees to 47 degrees, depending upon the manufacturer. Assuming the angle is 45 degrees, No. 2 cylinder fires 315 degrees of **engine** revolution after No. 1 while the engine turns through 405 degrees of revolution after No. 2 fires before No. 1 fires again. Since the magneto gives two sparks per revolution it is driven at half engine speed, therefore, the sparks it delivers must be spaced 157½ degrees and 202½ degrees of **magneto** revolution apart. This is accomplished by advancing the second spark (normally occurring 180 degrees after the first spark) 22½ degrees. This is done by moving the point of maximum change of flux ahead a similar amount. Since the relative positions of the pole shoes and armature determines this point the desired result may be obtained by altering the shape of the pole shoes and armature.

Figure 169 shows the pole shoes and armature of the Bosch Magneto designed for twin-cylinder motor-cycle ignition. The tips of each pole shoe are cut away and opposite sides of each half of the armature core are almost entirely removed.

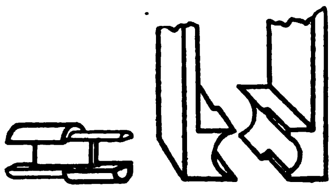


Fig. 169 — Bosch pole shoes and armature for motor-cycles

When the armature core is in the position shown at *A* (Fig. 170) the lines of force flow from the north pole across the small air gap *A* and through the core diagonally. They enter the south pole by flowing across the similarly small air gap *A* at the opposite (far) end of the armature core. They do not pass straight through the armature core because the large air gaps *B* offer a much harder path.

The point of maximum current *B* in the primary will be when the armature has just cleared the trailing pole tips *C* and *D* as in the usual construction.

When the armature core has reached the position *C* the lines of force flow from the cut-away part of the north pole shoe across the small air gap *A* diagonally through the armature core. They then pass into the cut-away south pole shoe by flowing across the similarly small air gap *A* at the opposite (near) end of the armature core. They do not pass straight through the armature because of the large air gaps *B*.

The second point of maximum induced current in the primary will be when the armature has just cleared the cut-away trailing pole shoe tips at *E* and *F*. In this case, however, the impulse of current will come earlier with respect to the movement of the arma-

ture than in the first case by the amount that the pole tips are cut away. This amount may be varied and in the case just considered would have to be equivalent to 22½ degrees of armature rotation.

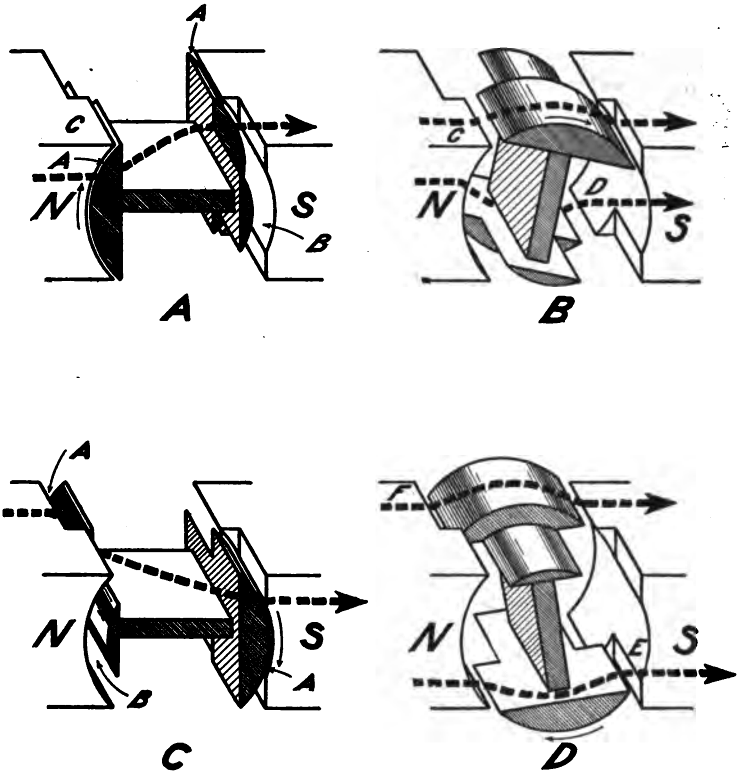


Fig. 170 — Change of magnetic flux in motor-cycle magneto armature

Thus the second spark is moved up 22½ degrees nearer the first spark which is the proper amount for a 45-degree V-type twin-cylinder engine.

Other methods of producing this same result have been devised with varying degrees of success. One common construction is to cover part of the pole shoes with brass which cuts off the lines of force emanating from that particular part. Another is to cut a narrow groove in the pole shoes which produces almost the same effect when the armature leaves the edge of the groove as when it leaves the pole shoe tip. Figure 171 shows this construction employed in the Berling Magneto. In this way impulses of induced current are obtained at two different points, the primary being broken first at one and then at the other. The

distance between the grooves in the pole shoes and the pole shoe tips depend upon the angle between the cylinders of the engine.

Fig. 171 — Berling construction for motor-cycles

Bosch Magnetos

Bosch magnetos are manufactured in many types and are designated by a combination of letters and numbers engraved on the base plate of the magneto. The letters represent the general construction, the number specifying the engine with which the magneto is to be used. For example Du4, the letters represent the type and the "4" specifies that it is for a four-cylinder engine. A few of the typical constructions will be explained so as to gain a general knowledge of these types of magnetos. The principle upon which they are constructed is the same as any shuttle type of armature.

The most common types in use are the "Du" magnetos constructed for engines of from one to six cylinders. The four-cylinder design is shown in Fig. 172. The six-cylinder type differs only in that it has a distributor arranged with six segments and terminals and the internal gearing so arranged that the distributor is driven at half engine speed when the magneto is properly installed on the engine.

Fig. 172 — Bosch Du4 magneto

Figure 173 shows a cross-section of this magneto and the solid black represents insulating material. Figure 174 shows the wiring of the magneto and in explaining the path of the primary and secondary circuits the numbers of the parts in Fig. 173 will be used to give a clear conception of the path the current takes.

Primary Circuit. — One end of the primary winding which consists of a few turns of heavy wire is in metallic connection with the armature core. The other end is connected to the condenser

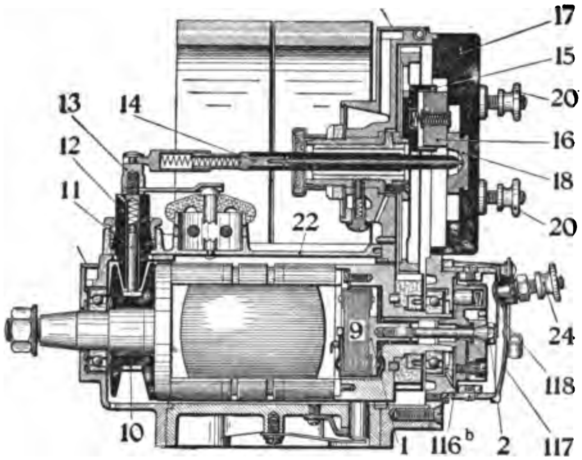


Fig. 173 — Cross-section of Bosch magneto

plate *1*. The interrupter fastening screw *2* which screws into plate *1* conducts the primary current to the insulated contact block supporting the long platinum screw *G–2* of the magneto interrupter.

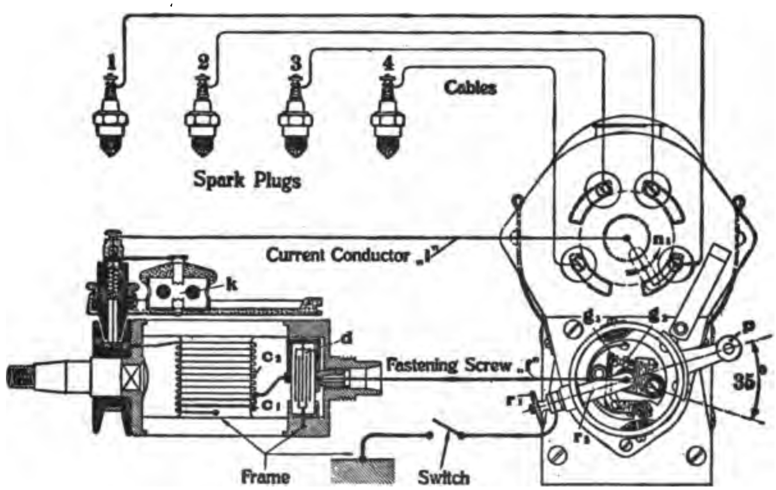


Fig. 174 — Internal wiring of Bosch magneto

The interrupter lever carrying the short platinum contact *G–3* is mounted on the interrupter disc which is electrically connected to the armature core. The primary circuit is complete when the two

platinum points are brought together and interrupted whenever these points are separated. The separation of the platinum points is controlled by the action of the interrupter lever as it bears against the steel segments screwed to the inner surface of the interrupter housing (timing lever housing). There are two segments in this housing so that the circuit is broken at the two points of maximum current in the primary. The condenser *9* is connected across the interrupter points so as to stop the arcing. One side is connected to the condenser plate *1* and the other side is connected to the armature core.

Secondary Circuit. — The secondary winding is composed of a great number of turns of fine wire. One end is connected to the primary and the other end to the insulated current collector ring (slip-ring) *10* mounted on the armature at the driven end. The slip ring is made of insulated material with a continuous brass segment inserted. In contact with this segment is the carbon brush *11* held by the carbon holder *12*. On top of the carbon holder there is a terminal *13* from which the current is conducted by the insulating bar *14* to the brass segment *18* in the center of the distributor. A brush holder *15* is mounted on a gear which meshes with a gear on the armature shaft so that the operation of the distributor will be in perfect synchronism with the armature. Carbon holder *15* contains a carbon brush *16* which conducts the current from the brass segment *18* to the segments which are embedded in the distributor plate *17*. These segments are connected with the terminal studs on the face of the distributor plate and the latter are connected by cables to the spark plugs in the various cylinders. In the cylinders the high tension current produces a spark and the current then returns through the engine to the magneto armature core, completing the secondary circuit. To protect the armature and other current carrying parts a saftey spark gap *K* is provided, connected between the terminal *13* and dust cover *22*. This gap is so arranged as to have more resistance than the gap at the spark plug under compression. Under ordinary conditions the current will flow through its normal path but if for any reason the resistance in the secondary circuit is increased to a high point, as when a cable becomes disconnected or the gap is too wide at the spark plugs, the high tension current will discharge across the safety spark gap. In this way the possibility of breaking down the insulating material of the instrument itself will be eliminated.

Cutting Out the Ignition. — Since high tension current is generated only on the interruption of the primary circuit, it is evident that in order to cut out the ignition it is necessary merely to divert

the primary current to a path which is not affected by the action of the magneto interrupter. This is accomplished as follows: Spring *118* being in contact with screw *2* leads the current to the insulated binding post *24* and if this binding post is connected to a switch having the other side grounded the primary in the magneto will be grounded at both ends when the switch is closed. Therefore, the operation of the interrupter will not break down the current flowing through it and consequently there will be no secondary current.

The ZR type of magneto is arranged for four- and six-cylinder engines and is identical in operation with that of the Du4 and the path of the current is identically the same. It differs in that it is a water-tight construction. When speaking of water-tight magnetos it is to be borne in mind that this does not imply that the magneto can be submerged in water for any length of time. It will withstand damaging effects of rain, moisture, or a stream of water squirted on it when the car is being washed. This is accomplished by the special construction of end plates and distributor with special terminal nuts as shown in Fig. 175. The edges of the oil covers are bent down and felt inserts used. Between the magnets there are strips of paper and felt washers.

Fig. 175 — Bosch ZR6 magneto

Figure 176 shows the distributor and timing lever removed from the magneto showing carbon brush and holder on the distributor gear wheel as explained in the Du4 construction.

The LT4 type magneto is designed for four-cylinder engines. It is in reality a modified ZR4 magneto, all electrical circuits being identical and water-proof construction being used. This type was especially designed for the Government, a distributor adopted as " standard " being employed. Other dimensions, such as height of shaft, taper of shaft, and dimensions of base plate are in accordance with Government specifications. This standardization permits of interchangeability of magnetos on Government apparatus regardless of manufacture, without tools or special equipment being used. This is of great assistance in the field, since a very quick change can be made and the necessity of carrying as spare equipment extra

magnetos of each make is eliminated. Figure 177 shows this magneto with the distributor and timer lever cover removed.

The B type of magneto is constructed for four- and six-cylinder engines and is identical in operation electrically as the Du4. It is of the water-tight construction. It differs mainly in its mechanical construction.

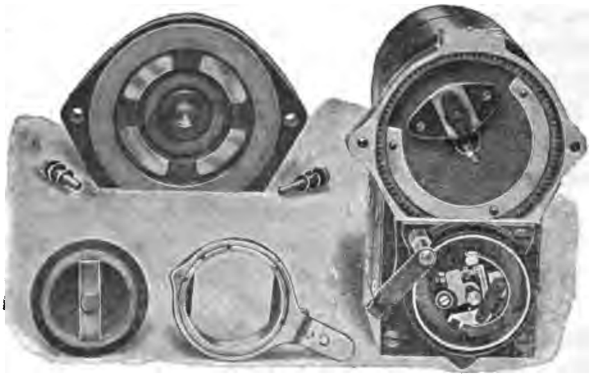


Fig. 176 — ZR4 magneto partially disassembled

The distributor instead of being mounted directly above the interrupter and driven by spur gears is mounted at the driven end (Fig. 178). The distributor is of the construction usually employed with battery ignition outfits and is of the jump spark type. The rotor of the distributor is driven by a vertical shaft operated by a

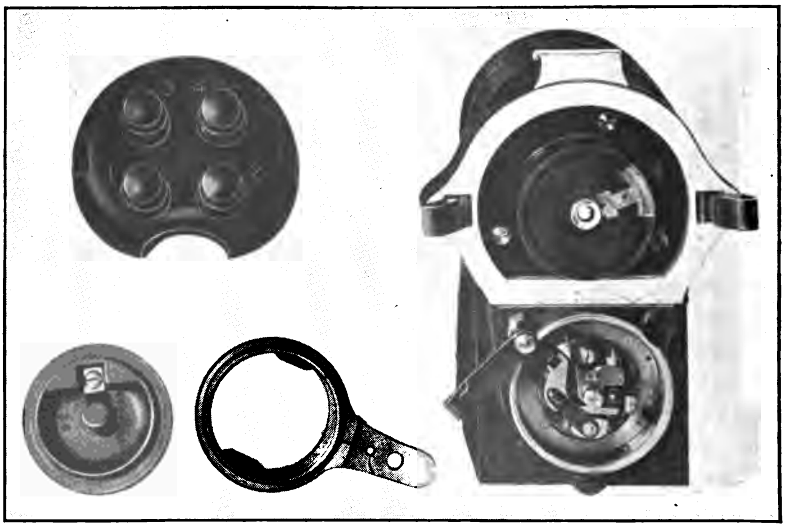


Fig. 177 — Bosch magneto standardized for military purposes

set of worm gears. The frame of the magneto is a single casting of aluminum. The pole shoes are moulded into the casting. By this method of construction it is entirely water-tight as there are no faces to be machined and assembled. The armature interrupter,

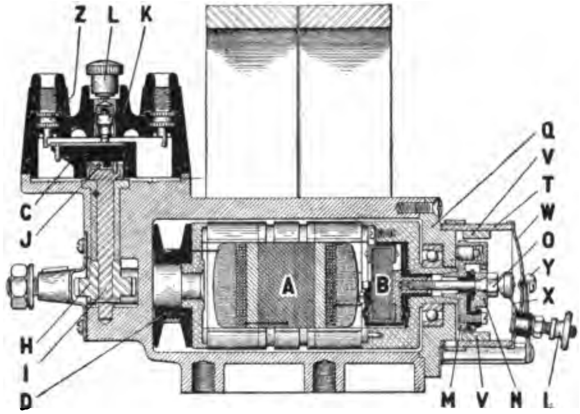


Fig. 178 — Bosch B4 magneto

condenser, pole shoes, and magnets are the same as used in the Du4 magneto. Thereby giving the same electrical efficiency.

The primary circuit in this magneto is the same as the other Bosch instruments. The secondary circuit differs only in that the current is led from the slip ring brush holder to the center terminal of the distributor by a cable.

Fig. 179 — Bosch ZEV magneto

The ZEV type of magneto (Fig. 179) is for a twin-cylinder motor-cycle engine and is a water-tight construction. As this magneto is used for motor-cycles which require the spark to occur at unequal intervals. The pole shoes and armature are cut away as previously explained. In every other respect the magneto is identical with the other Bosch Magnetos. In Fig. 179 the interrupter cover is removed showing that the cams are not set an equal distance apart, but are arranged to interrupt the circuit at the proper time to compensate for the cylinders being set at an angle.

The primary circuit in this magneto is the same as in all other Bosch Magnetos. The secondary circuit is slightly different. One

end of the secondary is grounded through the primary winding and the other end is connected to the segment of the slip ring. The slip ring in this type has a short segment instead of one that is continuous. In contact with this slip ring are two carbon brushes and holders which are placed one on each side of the magneto. In this manner the segment of the slip ring is in contact with only one brush when the primary circuit is interrupted during either half-revolution. Cables connect the spark plugs to these carbon holders so that the current is first led to one plug and then to the other.

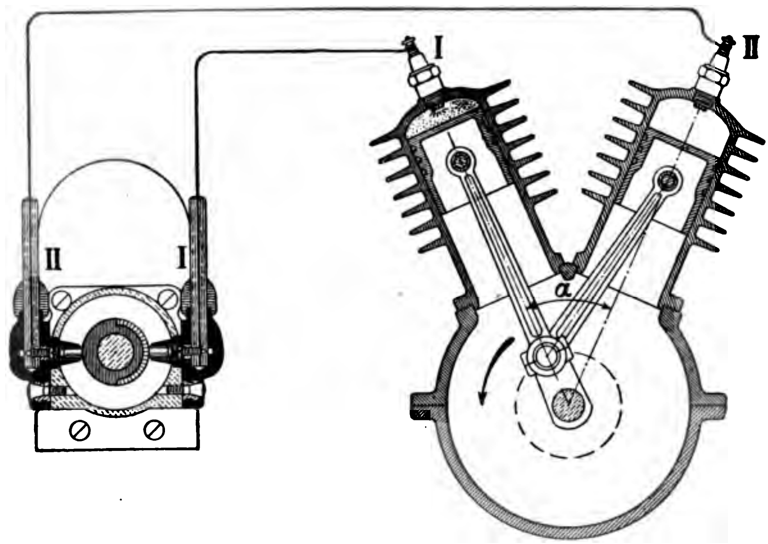


Fig. 180 — Wiring diagram of a twin-cylinder motor with a ZEV magneto

As the sparks are not equally spaced care must be taken to connect the proper carbon holder to the spark plug in No. 1 cylinder. Figure 180 shows the proper wiring from the carbon holders to the spark plugs in the cylinders.

Eisemann Magneto

The G-4 magneto is designed for four-cylinder engines and is made up in two general constructions, Edition I (Fig. 181) and Edition II (Fig. 182). The latter model is used more extensively than the Edition I. Figure 183 shows the internal wiring of these magnetos.

Primary Circuit. — One end of the primary is metallically connected to the core and the other end is brought out and spliced to a piece of cable. One end of the cable leads to the condenser which

Fig. 181 — Eisemann G-4 Ed I

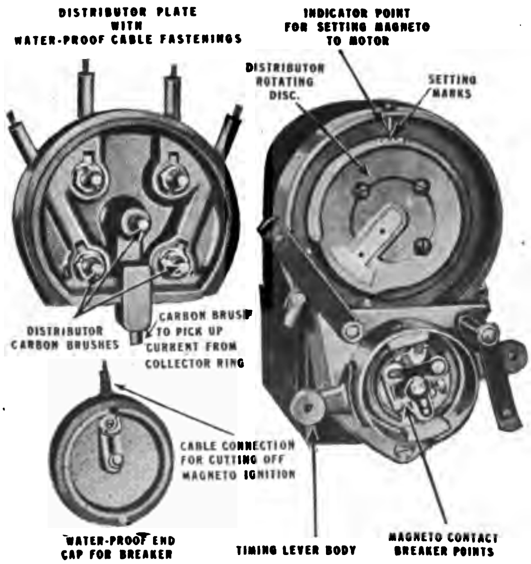


Fig. 182 — Eisemann G-4 Ed II

is installed at the driven end of the magneto in the armature housing, the other end being connected to the insulated terminal block *J* carrying the adjustable long platinum screw. In contact with this there is a short platinum stud which is attached to a spring fastened in a post which is grounded by the carbon brush *CB*. This makes a metallic return to the armature core of the primary circuit. When the platinum points are closed the circuit is made and when the platinum points are separated due to the action of the cam, the circuit is broken.

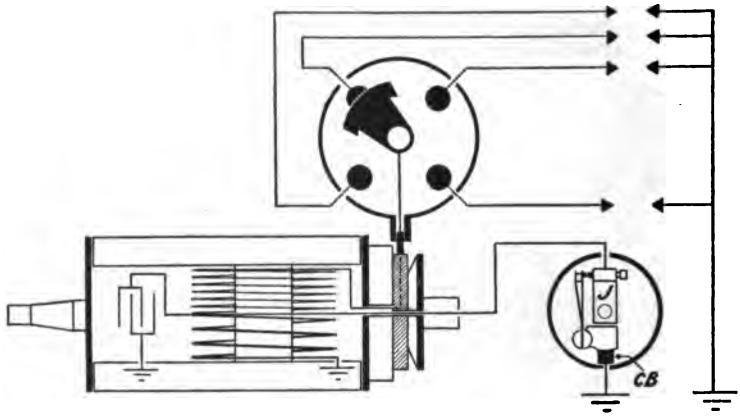


Fig. 183 — Internal wiring of Eisemann magneto

Secondary Circuit. — The secondary winding consists of a great number of turns of fine wire. One end is connected to the primary and the other end is connected to an insulated collector ring at the interrupter end of the magneto. The distributor is placed directly above the slip ring and has a carbon brush in contact with it. This carbon brush is metallically connected to a carbon brush in the center of the distributor. There are also four carbon brushes which are connected to the cables leading to the spark plugs. On the distributor gear wheel there is mounted an insulating plate with a brass segment embodied in it. This gear is meshed with the gear on the armature shaft so that they synchronize. The segment revolving with the distributor gear conducts the current from the center brush of the distributor to the four brushes in order. These carbon brushes being connected by cables to the spark plugs fastened in the engine, which is in metallic connection with the armature core, makes a complete path for the secondary current.

In the Edition I the interruption of the primary circuit is accomplished by fiber cams inserted in the timer lever body. In the

Edition II the interrupter is of a different construction (Fig. 181). The interruption is made by the use of steel segments attached to the timer lever body.

The method of short-circuiting the primary winding to put the magneto out of operation is as follows: A copper brush in the end of the screw holding the contact breaker in place is metallically connected to the end cap terminal which, when connected to ground through a switch, will short-circuit the primary winding. In the Edition II this varies slightly in that the carbon brush is in the end cap and bears against the interrupter fastening screw.

A few things to be noted about this magneto are that the condenser is so installed that it can be disconnected without interfering with the primary circuit. A grounded condenser could easily be detected by breaking this connection. Arranging the slip ring so that it is directly below the distributor eliminates several connections and makes the instrument more compact. Another point in favor of this location is that it is more protected than when located at the driven end of the magneto. Slip rings located at the driven end are often broken by inexperienced men when prying off gears or couplings.

Berling Magneto

Berling Magnetos are manufactured in many types. The most commonly used are the F-41 for four-cylinder engines and B-21 for

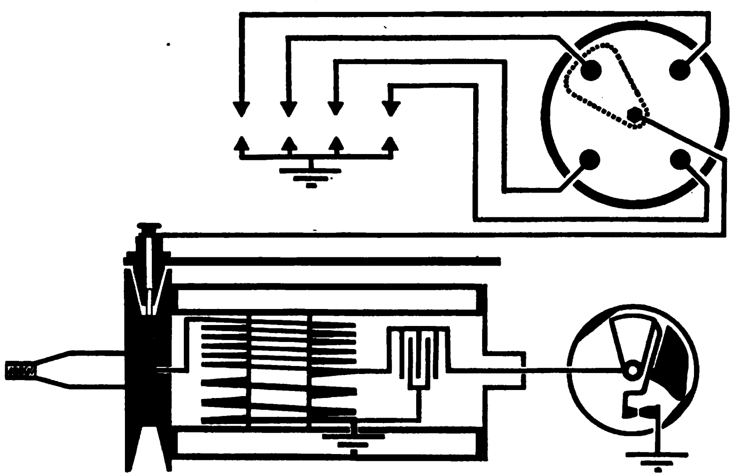


Fig. 184 — Internal wiring of Berling F-41

twin-cylinder motor-cycles. Figure 184 shows diagrammatically the internal wiring of the F-41 type.

Primary Circuit. — One end of the primary is grounded and the other end is led to the condenser plate. The interrupter fastening screw conducts the current from condenser plate to the insulated block of the interrupter carrying one of the interrupter contacts. The other contact is connected to ground and completes the circuit for the primary when the interrupter points are together. The separation of the points is accomplished by the lever as it bears against cams pressed in the surface of timing lever housing. The condenser is connected across the interrupter points, one side being connected to the condenser plate and the other to a wire which is grounded to the armature core.

Secondary Circuit. — One end is connected to the primary to obtain its ground return, the other end is brought out and connected to the slip ring. The slip ring has a continuous segment so that the brush which is held by the carbon holder is always in contact with it. From here the current is conducted to the rotor which is mounted on the distributor gear in mesh with a gear on the armature shaft so that they are in synchronism. The distributor is connected to the spark plugs by cables; thus the complete secondary circuit is made.

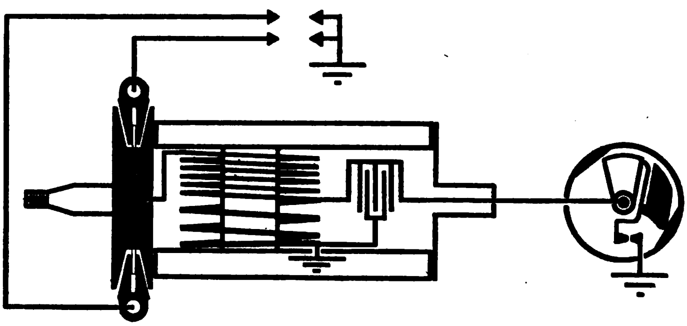


Fig. 185 — Internal wiring of Berling B-21

Figure 185 shows diagrammatically the internal wiring of the type B-21. The only difference in this wiring is that the slip ring has a short segment instead of a continuous segment as in the F-41. In contact with the slip ring are two carbon brushes so that the current generated in the first half revolution flows to one carbon brush and in the next half revolution to the other brush. Each of these brushes must be connected to the proper spark plug as previously explained (Fig. 180).

As this magneto is used on an engine which has the cylinders set at an angle it uses a special construction of pole shoes and also has the segments in the interrupter set to interrupt the circuit at the proper time.

Simms Magnetos

Simms Magnetos are manufactured in many types, and are designated by a combination of letters and numbers engraved on the base plate of the instrument, the letters representing the general construction and the numbers specifying the engine with which the magneto is to be used.

The most common types are the C- and K-series (Fig. 186). These are of the water-proof construction.

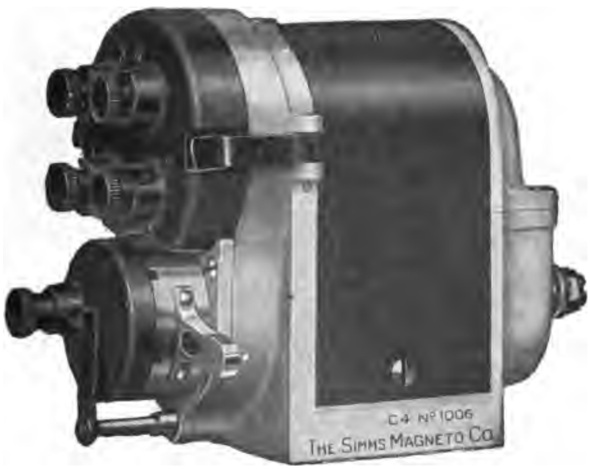


Fig. 186 — C4 magneto

The high-tension armature consists of a few turns of heavy primary wire over which are wound many turns of a very fine secondary wire. Only enamel insulated wire is used, and every layer is further insulated from the others with sheets of oiled silk. After being completely wound, the armature is impregnated alternately under compression and vacuum and then baked.

One end of the primary wire is grounded on the armature core, and the other end brought out to the contact breaker points, with the condenser in parallel to prevent the points burning (Fig. 187).

The grounded end of the secondary wire is connected to the primary, forming a continuation of same. The other end of the secondary circuit is led to the slip ring, then through the conducting bar to the distributor, spark plugs, and ground on the engine, to the magneto base plate, and back into the grounded end of the secondary.

When the contact points are closed, the primary circuit is also closed. The variations in the magnetic flux induce an electrical

current in it, which reaches its maximum twice every revolution of the armature. The primary circuit is then broken, inducing a high-tension current of extreme intensity in the secondary winding, which is distributed to the spark plugs, as mentioned above.

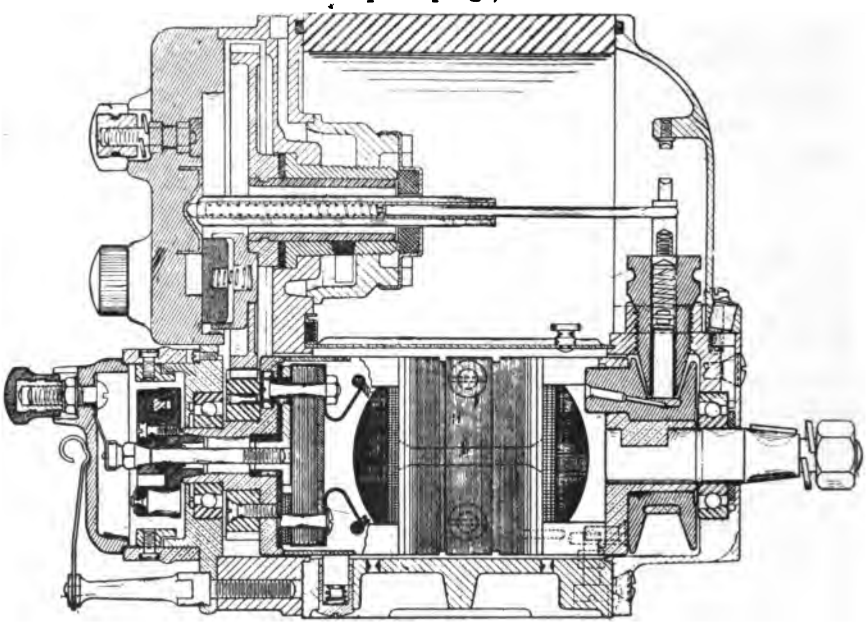


Fig. 187 — Sectional view of C4 magneto

The magnetos described in this chapter are typical of all Revolving Armature constructions. Except for minor details other magnetos of this type do not differ from those explained.

CHAPTER XVIII

MAGNETOS

ROTOR TYPE

All the magnetos discussed in the preceding chapter were constructed so that their windings revolved requiring insulated moving wires, collector rings, brushes, and moving contacts. In the revolving rotor type the windings are stationary, the rotor or inductor revolving between the pole pieces of the magnets conducting the lines of magnetic force through the soft iron core about which the stationary windings are placed.

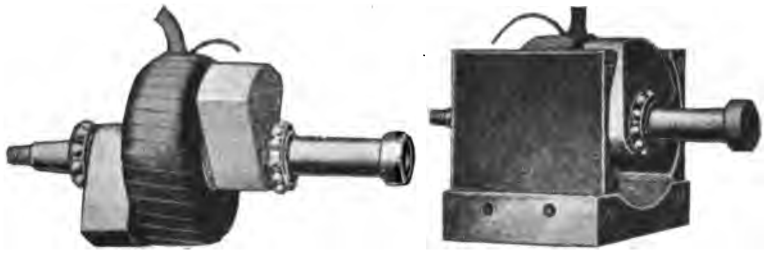


Fig. 188 — Rotor and winding

Figure 188 shows a rotor or inductor of the construction commonly used on this type of magneto. It consists of a steel shaft carrying laminated soft iron arms fastened to the shaft and projecting in opposite directions. These arms are shaped so as to reduce the air gap between them and the pole shoes to a minimum just as is done in the shuttle type armature.

Figure 189 shows several positions of the rotor with relation to the pole shoes during one revolution. Starting with the rotor at position A, all the lines of force flow from the north pole to the arm *R*, then at right angles through the shaft and out through the other arm to the south pole. If it is revolved clockwise it will next reach position B and fewer lines of magnetic force will flow through the rotor shaft. When it has revolved to position C the number of lines of force passing through the rotor shaft is still further decreased. When it has reached the vertical position D all the lines of force flow directly across from the north to the south pole through

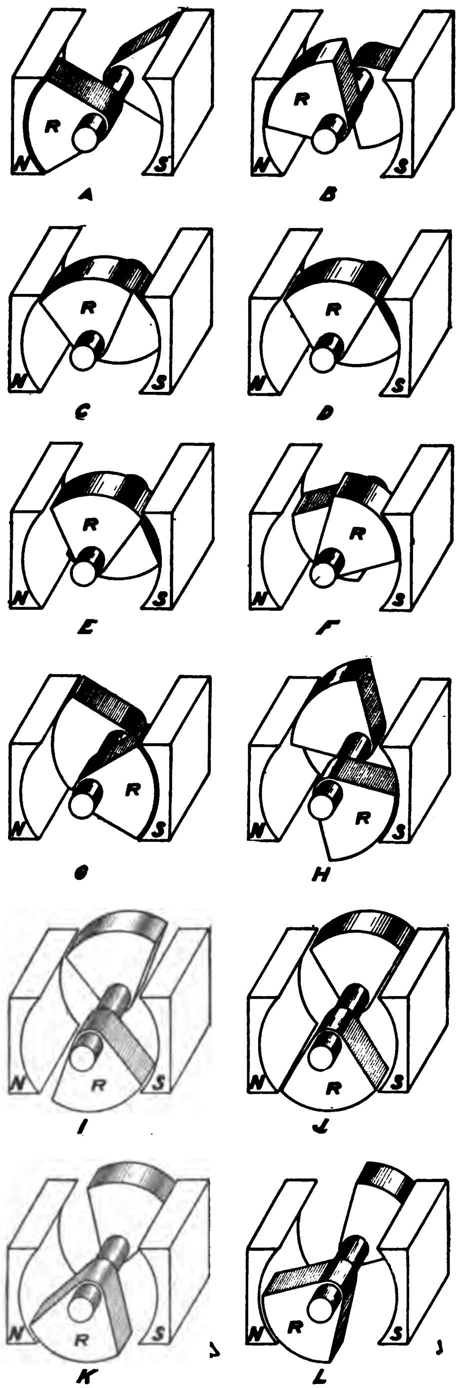


Fig. 189 — Change in flux through revolving rotor

the soft iron arms and none flow through the steel shaft. This is because the magnetic lines of force take the path of least resistance. As the rotor is revolved to position E, the lines of force start to flow through it again but in the opposite direction, leaving the rotor at arm *R*. As the rotor is revolved through the position F the number of lines of force flowing through it increases until it reaches a maximum when the rotor has reached position G. During the next half revolution as the armature revolves through positions H to L the same changes of magnetic flux through the rotor take place as during the first half revolution.

If the speed of rotation is uniform the rate of change of magnetic flux through the rotor is greatest as it approaches positions D and J. As already shown in Chapter 18 current is induced in a winding by causing a rapid change in the strength of the magnetic flux threading through it. This principle is applied in this type of magneto since the necessary varying flux is obtained by rapidly revolving the rotor.

If a stationary coil of insulated wire is wound about the steel rotor shaft, between the two soft iron arms as shown in Fig. 188, current will be induced in it whenever the rotor is revolved. Just as in the revolving armature type of magneto the maximum voltage induced in the winding will be when the rotor has just passed positions D and J (Fig. 189). The two maximum values will be equal but the flow of current will be in opposite directions. This is due to the reversal of the direction of magnetic flux through the rotor. Hence this type of magneto also generates alternating current.

If but one winding is used the resulting voltage will be low in value and for that reason magnetos of this construction are called Low Tension Magnetos.

When a secondary winding is wound on top of the stationary primary winding high tension current may be obtained from this type of magneto. The interrupter is in the primary circuit breaking it when the rotor is just beyond the vertical position. This breaks down the field caused by the current in the primary and induces a high tension current in the secondary.

The K-W Magneto

The K-W is a high tension magneto of the inductor type. The only revolving part in this magneto is the rotor (Fig. 190). This rotor differs from the one shown in Fig. 188 as the rotor arms are placed at right angles to each other and project from both sides of

the shaft. The same effect is obtained as if two rotors were used, that is, four impulses are induced per revolution instead of two.

Figure 191 shows how this is accomplished. The arrows indicate

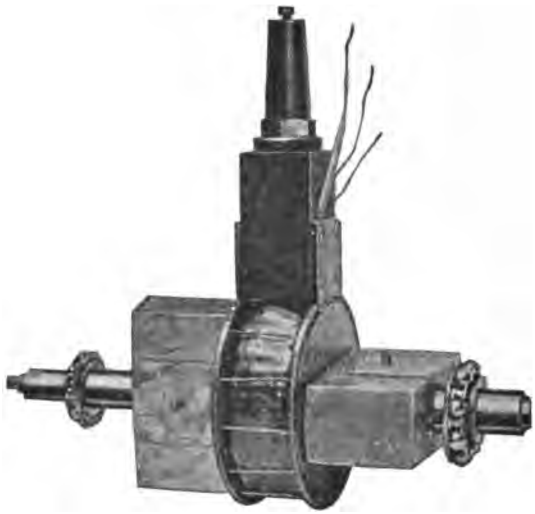


Fig. 190 — K-W rotor and windings

the path of the magnetic flux through the rotor at different positions. It will be noticed that the rotor in this construction does not revolve between the pole shoes but directly below them.

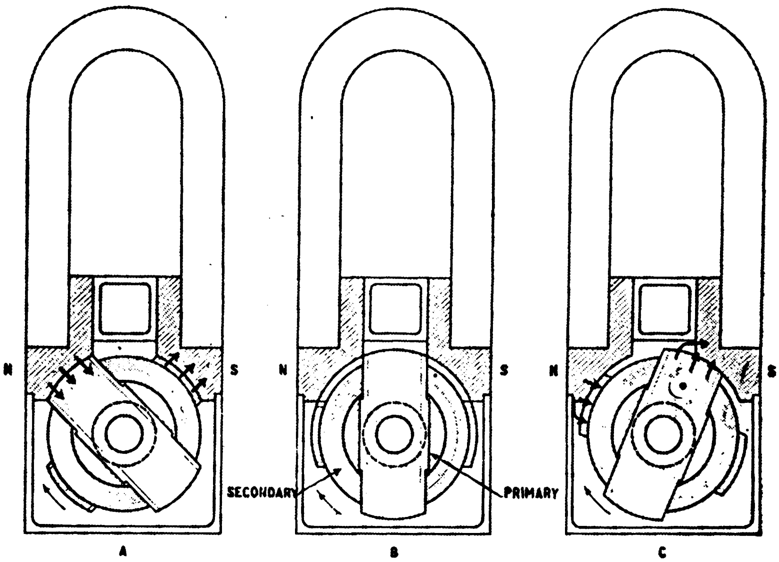


Fig. 191 — Path of flux in K-W magneto

The windings are stationary and composed of a primary and secondary concentric with the rotor shaft (Fig. 190). The interrupter is wired in the primary circuit as usual and the condenser is connected across the contact points. The condenser is located inside the magnets at the shaft end of the magneto. The interrupter normally has a two-nosed cam, driven by the rotor shaft, so that the current in interrupted in the primary at but two of the four points where it is a maximum. Therefore, it must be driven at the same speed as a revolving armature type of magneto.

The current from the secondary passes directly to the insulated terminal on top of the windings. From this point the high tension lead conducts it to the central terminal of the distributor which distributes it to the various cylinders of the engine. The saftey spark gap is also connected to this terminal and is located just above the condenser.

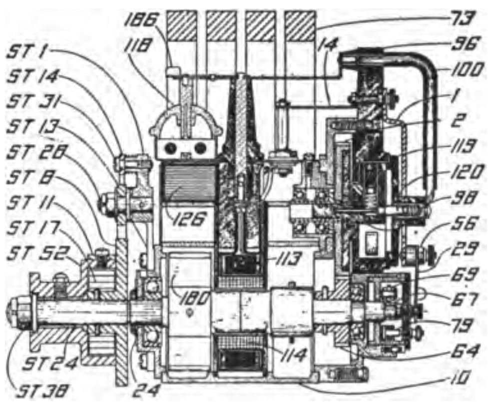


Fig. 192 — Cross-section of K-W magneto

Figure 192 shows a cross-section of the K-W magneto, the various windings and connections being shown.

There are several K-W magnetos, the models being designated by letters in the usual manner. When the letter K is part of the designation it indicates that the magneto is equipped with an impulse starter such as already explained in Chap. 18.

The Dixie Magneto

The Dixie is a high tension magneto of the inductor type. The rotor as usual is the only revolving part, but it differs considerably in construction from those previously described.

Figure 193 shows the arrangement of the magnets and rotor. One arm of the rotor always conducts magnetic flux from the north pole of the magnets while the other conducts it to the south pole. To prevent magnetic flux from flowing between the arms of the rotor the central part is made of brass which is a nonmagnetic substance. The rotor revolves between pole shoes *F* and *G* of soft iron connected by a core *C* upon which the windings are placed.

Fig. 193 — Magnets and rotor of Dixie magneto

When the rotor is in the position shown at *A* (Fig. 194) the magnetic flux takes the following path. From the north magnetic pole through the rotor arm *N*, pole shoe *G*, core *C*, pole shoe *F*, rotor arm *S*, to the south magnetic pole. When the rotor has turned to the position shown at *B*, the path of the magnetic flux is as follows: From the north pole of the magnet through the rotor arm *N*, to both pole shoes *F* and *G*, directly to the rotor arm *S*, and thence to the south pole of the magnet. With the rotor in this position none of the lines of force set up by the permanent

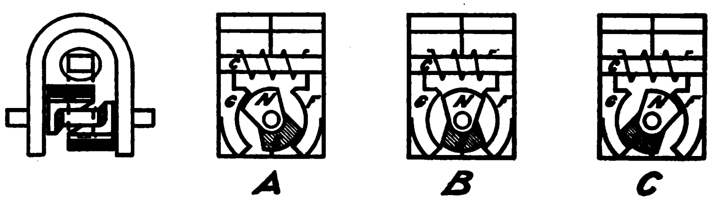


Fig. 194 — Path of flux in Dixie magneto

magnets flow through the core *C*. When the rotor has turned to the position shown at *C* the magnetic flux takes the same path as at *A* but passes through the pole shoes and core in the reverse direction. Thus a rapid change of flux through the core *C* is obtained which induces a current in the primary winding. This current will be a maximum when the rotor has just passed the vertical position. If the primary circuit is interrupted when the current is a maximum, a current of high voltage will be induced in

the secondary. Since there are but two points at which the current is at a maximum during each revolution the interrupter will have a two-nosed cam which gives two sparks per revolution.

Figure 195 shows the waterproof covering and one magnet removed from a Dixie Magneto. When the timing lever is moved in advancing or retarding the spark the pole shoes and coil are moved a corresponding amount. In this manner the primary circuit is always interrupted at the point of maximum current.

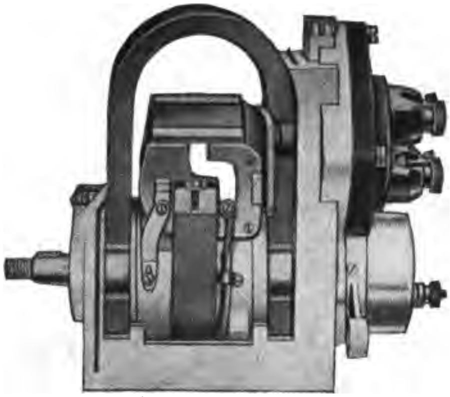


Fig. 195 — Dixie magneto

The interrupter cam is driven by the same shaft as the rotor. One contact is grounded and the other connected to the ungrounded end of the primary. The condenser is located on top of the windings and is connected across the contact points. One end of the secondary is grounded through the primary and the other is connected to the rotor of the distributor. Figure 196 shows diagrammatically the internal wiring of the Dixie Magneto.

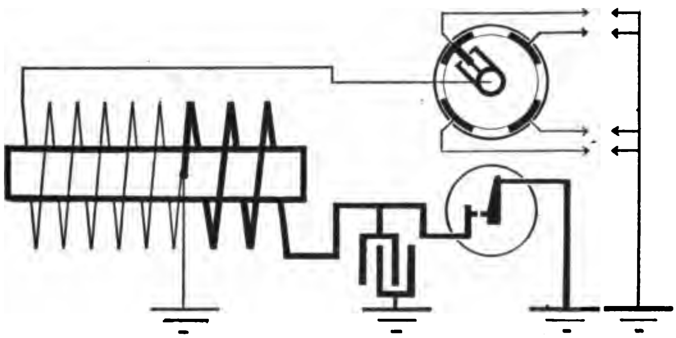


Fig. 196 — Internal wiring of Dixie magneto

The Dixie Magneto constructed for use on twin-cylinder motorcycles has no changes in its pole shoe or rotor construction. The interrupter cam is arranged to break the primary circuit at unevenly spaced intervals to compensate for the angle at which the cylinders are placed. This causes one spark to be delivered when the rotor is just leaving the trailing pole shoe while the other occurs

after the rotor has turned a considerable distance beyond the trailing pole shoe. This same relation is always maintained whether in the advance or retarded position because of the movable pole pieces in the magneto.

Scintilla Magnetos

The Scintilla Magneto is a high tension magneto of the inductor type and differs in its construction from the other inductor types of magnetos in that the permanent magnet is revolved instead of having stationary magnets.

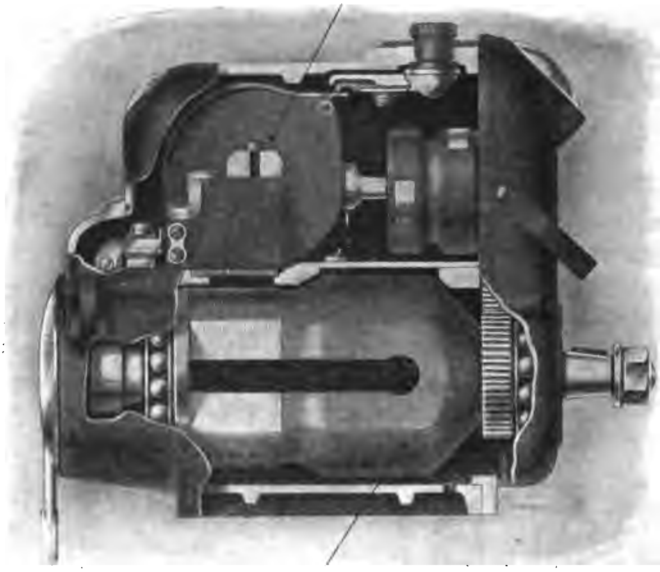


Fig. 197 — Scintilla magneto

The magnet, winding, and distributor rotor are shown in Fig. 197, a cut-away section of the instrument. The interrupter, the winding, safety spark gap, and distributor carbon brushes are all stationary. This instrument has all its parts encased so that it is entirely water and dust proof.

The operation of this instrument is similar to the other inductor types in that the magnetic flux is taken from the revolving magnet by the iron pole shoes which extend above the magnet and carry the magnetic flux to the core of the winding (Fig. 198).

As the magnet revolves it causes the reversal of the magnetic flux in the core of the winding, thereby setting up an electrical

current in the primary winding. The interrupter, breaking the primary circuit at the proper time, causes the high tension current to be induced in the secondary winding, which is led out to the distributor by means of a contact made with the ungrounded end of the secondary winding. The distributor of this instrument is different from the usual construction in that the rotor is built like a double slip ring and the distributor block is not of one solid con-

Fig. 198 — Section Scintilla magneto

struction, but is made in two pieces with the brushes operating on the rotor. The distribution of the current from the distributor is the same as with any other type of magneto.

The feature of this magneto is, that instead of having the magnet stationary and taking the magnetic flux by means of rotors, the magnet itself is revolved and thereby decreases the amount of air gaps which are usually found in the inductor type of magnetos.

CHAPTER XIX

DUAL AND DUPLEX IGNITION SYSTEMS

When a magneto is used on a heavy engine which cannot be turned by hand at a sufficiently high speed to produce a spark and the engine does not employ an electric starter, a battery ignition system may be used to obtain a spark at low speeds. This led to the adoption of two independent ignition systems employing a battery ignition system for starting and a magneto for continuous operation. With this arrangement two spark plugs were required in each cylinder, one for the battery ignition system and one for the magneto ignition system. As the battery plugs were not used while operating on the magneto they became sooted and short-circuited so that they would not operate when desired for starting.

To overcome this difficulty systems have been designed in which the magneto and battery ignition systems use the same set of plugs. These are called Dual or Duplex systems of ignition. In some cases a low tension magneto is used with a high tension coil, the primary of which is supplied with current either from the magneto or battery. In other types a high tension magneto is used and a separate induction coil for the battery. The only part used in common is the distributor of the magneto. A few types called Duplex employ a high tension magneto and a low tension vibrator coil which is wired in series with the primary of the magneto.

Remy

This is a low tension magneto using a high tension coil, the primary of which is supplied with current either from the magneto or from the battery.

Figure 199 shows diagrammatically the internal and external wiring of the Remy Dual ignition system. When the dash coil is switched to the "off" position all circuits are opened. When the switch is turned to the *M* (Magneto) position the battery circuit is open and the current is furnished by the magneto. In this position the switch is making connection between *A* and *B*.

The primary circuit is as follows: The current from the magneto primary winding, one side of which is grounded, flows from *G* at

the magneto to G at the coil which is connected to the switch at A and then across the switch plate to B. From here it flows through the primary of the coil to terminal Y on the coil which is connected to terminal Y on the magneto. The interrupter is connected between terminal Y and ground. When the points are together the circuit is made and when separated the circuit is interrupted, causing a breakdown of the magnetic field set up by the primary of the

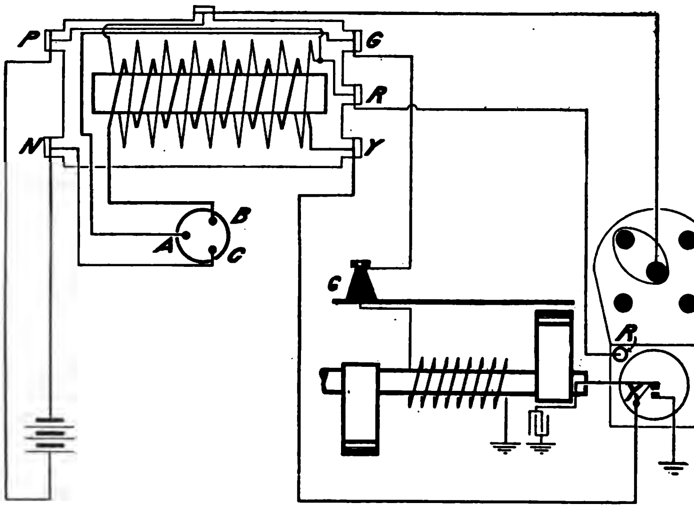


Fig. 199 — Internal wiring of Remy dual system

coil, inducing current in the secondary. The secondary circuit is as follows: One end is grounded at R on the magneto. The other end of the secondary winding of the coil is connected to the center terminal of the distributor from which it is distributed to the terminals wired to the plugs.

When the switch is turned to the B (Battery) position, the current is supplied to the primary of the coil from the battery instead of the magneto, the switch now connecting C and B.

The primary circuit is as follows: The current flows from the positive of the battery to a terminal P on the coil. Then it flows through a jumper in the coil to terminal R which is connected by cable to R on the magneto which is the ground terminal One side of the interrupter being grounded and the other side connected to Y the current takes this path when the interrupter points are closed. It flows to terminal Y on the coil which is connected to the primary of the coil. The other end of the primary is connected to B. As B and C are connected the current flows to the terminal N and back

to the battery making a complete circuit. When the interrupter points are separated the circuit is broken causing a collapse of the field set up by the primary of the coil thus inducing the secondary current. The secondary circuit is the same as when operating on magneto.

This is the typical arrangement when a low tension magneto is used for dual ignition and all other systems vary but little from this in any respect except switch connections.

Bosch Dual

In this system a high tension magneto is used and also a high tension coil with battery. They work independently of each other except that they both employ the same distributor.

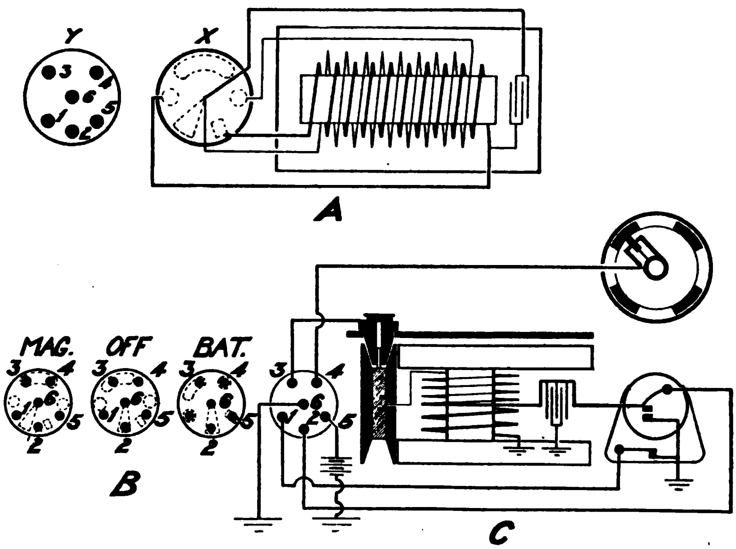


Fig. 200 — Internal wiring of Bosch dual system

Figure 200 shows digrammatically the internal wiring of the coil and magneto of the Du-4 Dual ignition system as well as the external connections from the magneto to the coil. At *A* is shown the internal wiring of the coil and its connections to the movable switch plate *X*. At *B* is shown how the segments in the movable switch plate connect the terminals of the fixed switch plate *Y* when in different operating positions. At *C* is shown the internal connections of the magneto and how they are wired to the fixed switch plate *Y* of the coil. It is to be noted that the magneto has two interrupters as shown in Fig. 201. One is for the magneto and one

for the battery ignition system, each being electrically independent of the other.

When the coil is switched to the *M* (Magneto) position the battery circuit is broken as the terminal *5* is not in contact with any segment on the movable switch plate. The primary circuit of the magneto is as follows: One end of the primary winding is grounded. The other end is led to the interrupter contact point *P* which is in connection with contact *Q* which is grounded.

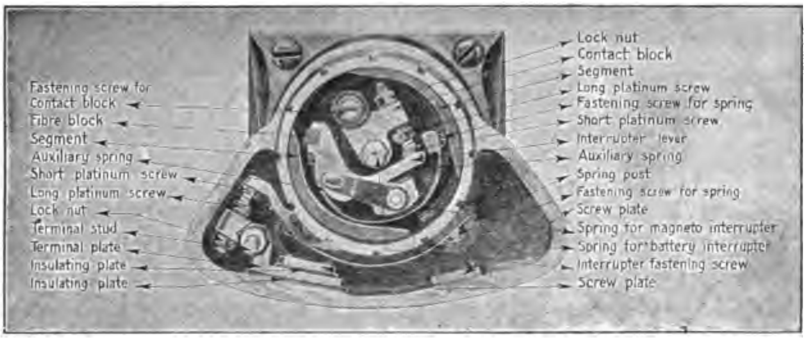


Fig. 201 — Dual interrupters

The secondary circuit is as follows: One end of the secondary winding is connected to the primary and the other end is connected to the slip ring. Carbon holder *3*, the brush of which is in contact with the slip ring, is connected to terminal *3* on the switch plate of the coil. A segment of this movable switch plate connects terminals *3* and *4* so that the current is led to the distributor and then to the plugs. The battery or coil windings do not enter into the circuits when operating on magneto.

If the switch is turned to the "off" position shown at *B* the movable switch plate makes connection between terminals *2* and *6* which short-circuits the primary of the magneto putting it out of operation. The battery circuit is still broken as the terminal *5* is not connected to any segment of the movable switch plate. Therefore, the battery system is out of operation.

When the coil is switched to the *B* (Battery) position number *2* terminal is still connected to ground so that the magneto is out of operation. Terminal *5* is now connected to the segment shown as a square on the movable switch plate. The battery current passes through the primary of the coil and to terminal *1* of the switch plate which is connected to the battery interrupter on the magneto. The secondary winding of the coil has one end attached to the segment of the movable switch plate which is in contact with

terminal *6* and is grounded. The other end of the secondary winding is connected to the segment on the movable switch plate which is now in contact with terminal *4*. This terminal is connected to the distributor of the magneto from which the current is led to the spark plugs.

The only part used in common for the magneto and battery systems is the distributor so that in reality two complete ignition systems exist independent of each other except that they use the same distributor and plugs. This condition is ideal and it gives two separate systems so that if one goes dead the other can easily be used. This design is typical of all systems employing a high tension magneto in a dual system of ignition.

Vibrating Duplex System

In order to obtain a system which would be simple and not require a separate high tension coil, a construction called the vibrating duplex system has been designed and used by many ignition manufacturers. It consists of a switch and a low tension vibrator coil which is wired in series with the primary of the magneto. In this way the battery supplies the necessary current to the primary of the magneto and the vibrator interrupts it so as to get the induced secondary current.

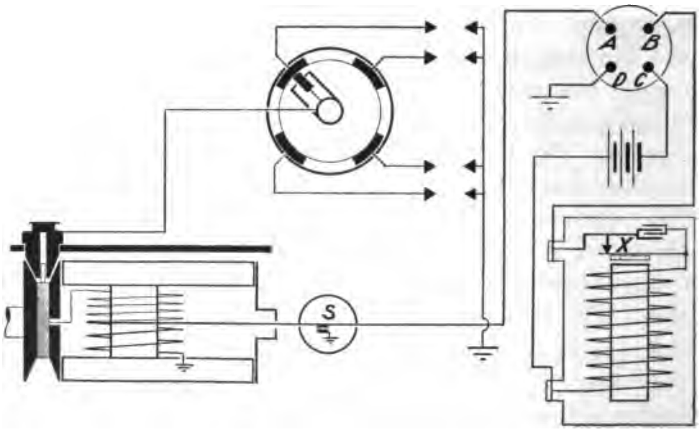


Fig. 202 — Internal wiring of Duplex system

The connections in this system are made as shown in Fig. 202. One side of the battery is connected to the coil and the other side is connected to the terminal *C* of the swtich. Terminal *D* is connected to ground and terminal *B* is connected to the other terminal of the coil. Terminal *A* is connected to the short-circuiting terminal of

the magneto. When the switch is in the "off" position it connects *A* to *D* which short-circuits the primary of the magneto. Terminal *C* is free so that the battery circuit is broken.

When the switch is turned to the "battery" position terminals *C* and *D* are connected and likewise *A* and *B*. The current from the battery now passes through the vibrator coil and to terminal *S* at the magneto. If the interrupter points are closed the current will be grounded through them and the vibrator will vibrate but the primary of the magneto does not receive any of the battery current. When the interrupter points are separated the current must pass through the primary of the magneto to get to ground and every time that the vibrator interrupts the circuit an induced current will be set up in the secondary. In this way a spark or series of sparks will be produced even if the magneto is at a standstill or revolving slowly.

When the switch is turned to the magneto position all the contacts at the switch are open so that the battery circuit is broken and the magneto is not grounded. It will thus operate as an independent high-tension magneto.

With this system the advantage of having battery ignition for starting and magneto for operating has been obtained but its entire operation depends upon the magneto so that any trouble with the magneto puts the entire system out of operation.

CHAPTER XX

STARTING AND LIGHTING SYSTEMS

One of the greatest improvements in the equipment of modern motor vehicles has been the adoption of electric starting and lighting systems. The unhandy and troublesome lights formerly used have been replaced by efficient electric lights ready to illuminate the road at a moment's notice. The task of cranking the engine by hand which was always laborious, and sometimes dangerous, has been eliminated and the engine is now spun easily whenever desired by an electric cranking motor.

Starting and lighting systems are generally divided into two classes: first, single-unit systems; second, two-unit systems. In the first a single piece of electrical apparatus, a motor-generator, furnishes the current for charging the storage battery, for ignition, and for operating the lights and also acts as a motor for cranking the engine. The two-unit system has a generator for furnishing the current and a separate motor for cranking the engine.

In order to understand the operation of motors and generators a brief explanation of the principles upon which they operate will first be given.

The generator does not actually create electrical energy as might be implied from its name. It simply generates or produces an electro-motive force by means of electro-magnetic induction which causes current to flow. The electrical output of a generator depends upon the mechanical energy supplied to drive it. Hence a generator is a piece of electrical apparatus for transforming mechanical energy into electrical energy in the form of induced electro-motive force. This force causes electricity to flow through the **external circuit** from the positive terminal or point of high potential to the negative terminal or point of low potential, just as water flows from a higher to a lower level. In the **internal circuit** electricity flows from a lower to a higher potential due to the induced electro-motive force just as water is pumped from a lower to a higher level.

Generators and motors are classified according to their design and mechanical construction.

1. Direct current machines.
2. Alternating current machines.

The current in the internal circuit is always alternating just as in the magneto but may be made direct current in the external circuit by employing suitable moving contacts called a commutator. Since only direct current machines can be used for starting and lighting systems because of the storage battery, alternating current machines with the exception of the Ford magneto will be discussed in this chapter.

The simplest form of generator may be made by revolving a closed loop of wire in a magnetic field. Figure 204 shows a loop of wire mounted on a shaft which may be revolved in the magnetic field existing between the north and south poles as shown. If the loop is revolved as indicated by the arrow the following will result. In the position shown there will be no induced electro-motive force in the loop since all the lines of force thread through it. As it turns through one-quarter of a revolution the number of lines of force threading through the loop are diminished at a constantly increasing rate until it reaches the dotted position where no lines of force thread through it. The induced electro-motive force depends upon the rate of change of the lines of force threading through the loop and will therefore be greatest when the loop is moving across the pole faces with a maximum value when the loop is in the dotted position. Applying the right-hand rule (Fig. 121) the direction of the current flow is that indicated by the arrows in Fig. 204. During the second quarter revolution the lines of force thread through the opposite side of the loop. The rate of change and consequently the electro-motive force decreases until both are zero again when one half revolution has been completed. During the next half revolution the same variations in the induced electro-motive force occur but in the opposite direction. The current is reversed twice each revolution, an alternating current flowing around the loop.

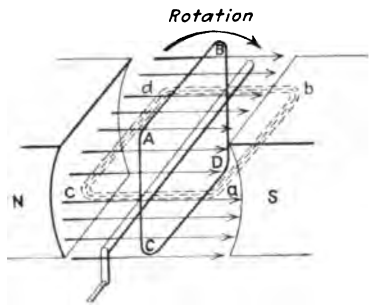


Fig. 204 — Principle of generator

To utilize the current flowing in a closed loop when it is rotated in a magnetic field some mechanical device must be used to lead the current from the rotating loop so it will flow through an external circuit. This is accomplished by attaching the ends of the loop to metal contacts against which are held stationary pieces called brushes. If each brush is connected first with one end and then

with the other end of the revolving loop and the change is made at the instant the current in each side of the loop is reversing, the current in the outside circuit will always flow in the same direction. This is accomplished by means of a commutator (Fig. 205).

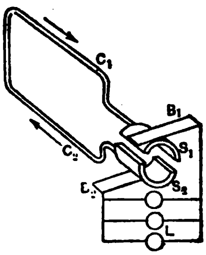


Fig. 205 — Simple commutator

The simplest form of commutator consists of a split ring the segments *S–1* and *S–2* being insulated from each other and also from the shaft. The brushes *B–1* and *B–2* rest on the commutator at diametrically opposite points collecting the current and delivering it to the lamps *L*.

Assuming that the current in *C–1* is flowing to the brush *B–1* the current in *C–2* must be flowing in the opposite direction or away from brush *B–2*. Hence *B–1* is positive and *B–2* negative. The brush *B–1* bears on the segment *S–1* as long as the current in *C–1* continues to flow in this direction. At the instant the current in *C–1* starts to flow in the opposite direction the segment *S–1* leaves this brush and *S–2* just makes contact with *B–1*. The current in *C–2* has also reversed and now flows to segment *S–2*. Hence *S–2* now delivers current to brush *B–1* which still continues to be the positive brush. In the same way brush *B–2* is always the negative brush and the current delivered to the lamps always flows in the same direction.

When but a single loop of wire is used the induced electro-motive force will necessarily be low. By increasing the number of turns, the induced electro-motive force is increased proportionately. With a single loop, the current delivered will not be steady although always in the same direction. The variations in the current flow are due to the change in the induced electro-motive force from a maximum to zero as the loop is revolved. If another loop is placed at right angles to that shown in Fig. 204 the current flow in this loop will be a maximum when it is zero in the other loop. As the two loops are revolved the current flow in one increases as that in the other decreases giving a less pulsating current in the external

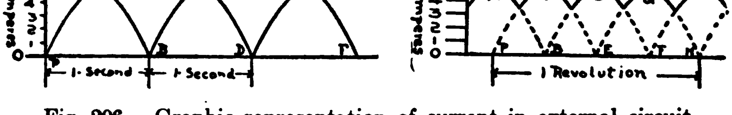


Fig. 206 — Graphic representation of current in external circuit

circuit. Figure 206 shows graphically the difference between the current delivered by a single loop and that delivered by two loops

at right angles to each other. By equally spacing a great number of coils a continuous current output and high electro-motive force is obtained.

To concentrate the magnetic field between the poles of the field magnets and also to support the coils of wire a laminated armature of soft iron is used.

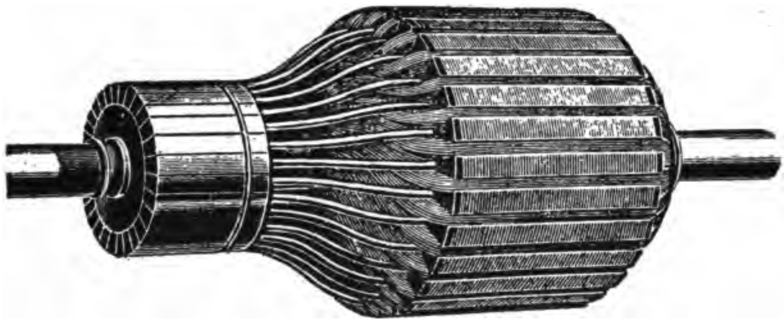


Fig. 207 — Drum type armature

The armature may be ring-shaped with the coils wound around it or it may be of the slotted-drum type (Fig. 207). The latter is the type of armature universally used on starting motors and lighting generators. Although the armature coils are all connected in series with each other there must be a commutator segment for every coil of wire wound on the armature. This is necessary so that the current flowing in any particular coil has a path through the brushes to the outside circuit at the instant the current flowing in it is a maximum.

Fig. 208 — Curved slot armature

To obtain a more even flow of current some armatures, instead of having the slots straight, have slots curved (Fig. 208). In this manner instead of having the slots of the armature leaving the pole shoes abruptly and giving a series of high peak, they leave the pole shoes gradually and give a more even curve of output. With this type of armature the whistling noise is materially decreased. It

also gives a better circulation of air, which tends to keep the machine cooler.

Commutators are built up of copper segment insulated from each other by mica inserts. These segments are usually held together by cones on the inside. Figure 209 shows a cross-section view of

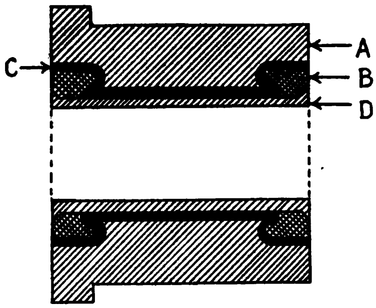


Fig. 209 — Sectional commutator

a built-up commutator. The copper bars marked *A* are formed on the inside as shown. The cones *B* fit into the machined recess in the copper bars. Mica insulations *C* are placed between the cones and the bars so that they are insulated from the ground.

The steel tube *D*, also insulated by mica from the copper bars, holds these cones together by the turning over of the ends. This tube forms the inside of the commutator to fit over the shaft. The commutator is machined on its outer circumference to the exact size for the proper brush setting. The mica is undercut so that the copper bars are slightly raised above the mica.

In order to set up a strong magnetic field between the pole pieces, the field magnets of motors and generators are electro-magnets. Part or all of the current generated in the armature is sent through coils of wire wound on the field pieces. Of course no current would be generated in the armature at starting if there was not some magnetic field existing between the pole pieces. The soft iron field pieces retain sufficient " residual " magnetism to set up a weak field which in turn generates a weak current. This current flows through the field windings increasing the magnetic field which in turn increases the generated current. In this way the machine " builds up " until it has reached its normal operating condition.

Field windings may be arranged in any of the following ways: series, shunt, or compound.

Figure 209a shows a simple two-pole machine in which all the current generated in the armature passes through the field coils. Hence, heavy wire is used to carry the current and but a small

number of turns are necessary to give the desired strength of magnetic field. This is known as a series wound machine. Generators of this description are not used for lighting motor vehicles. This is because the voltage varies greatly when the resistance of the

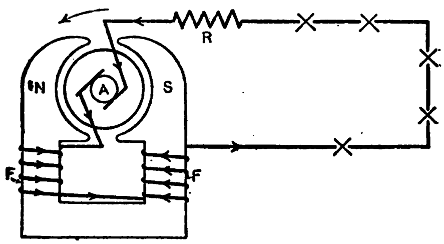


Fig. 209a — Series generator

external circuit is changed hence they are only suitable for supplying practically constant current. Series wound motors, however, are always used because of the great starting torque obtained. This will be discussed more fully later in this chapter.

Figure 210 shows the field windings so arranged that only part of the current generated in the armature flows through them. Hence,

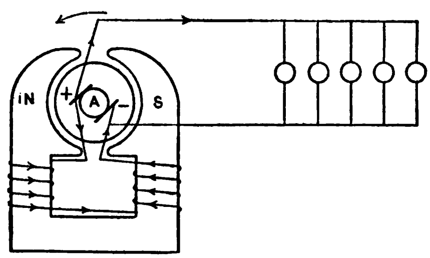


Fig. 210 — Shunt generator

fine wire is used and a great many turns are necessary to produce the desired strength of magnetic field. This is known as a shunt wound machine. A shunt generator " builds up " in the same way a series generator does. The voltage of a shunt wound generator falls off as the load on it is increased but when used as a lighting generator the storage battery carries any extra load keeping the voltage constant on the line. Shunt wound starting motors are not used because of their low starting torque.

Figure 211 shows a two-pole compound wound machine. The field windings are made up of both shunt and series coils. When the field windings are arranged so that they oppose or " buck " each other the machine is said to be " differentially wound." When the

field windings are so arranged that they aid each other the machine is said to be " accumulative."

The operation of the motor depends upon the resultant field set up when a conductor through which current is flowing is placed in a strong magnetic field.

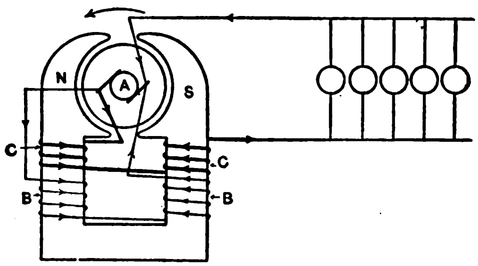


Fig. 211 — Compound generator

Figure 212A shows the field existing about a wire when current is flowing through it and Fig. 212B, the field resulting when it is placed in a uniform field flowing from left to right. The lines of force above the wire flowing to the right join those of the field flowing to the right and thus strengthen the field above the wire.

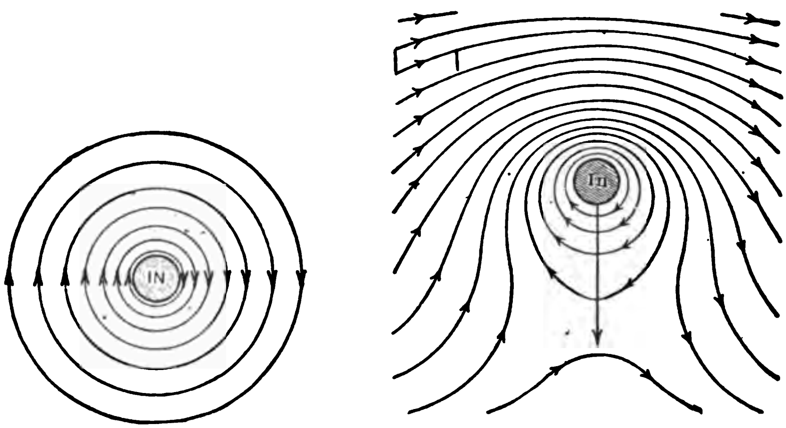


Fig. 212 — Field about a current carrying conductor

Those below the wire flowing to the left neutralize some of the lines of force flowing to the right and weaken the field below the wire. Thus a strong field is built up above the wire and a weak field below it resulting in a force which causes the wire to move **down** due to the elastic action of the lines of force.

Figure 213 shows the effect of sending current through a loop of wire free to revolve between opposite poles of a magnet. When

current flows in at A and out at B the field is weakened **below** A and **above** B. This causes the loop to revolve in a counterclockwise direction. When the number of loops and the strength of current passing through them is increased the turning force will be

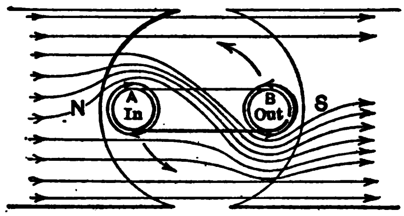


Fig. 213 — Principle of motor

greatly increased. When the field between the poles is strengthened by placing the coils on an armature and spacing them equally an even torque is obtained. This is identical with the construction used on generators. Sending current through the armature of a generator causes it to revolve and the machine becomes a motor. A motor, therefore, is a machine for transforming electrical energy into mechanical energy.

To determine the direction of rotation the **left** hand should be held as shown in Fig. 121 the middle finger indicating the direction the current is flowing through the coil and the forefinger the direction of magnetic flux. The thumb will then indicate the direction of rotation. When run as a motor current is always sent through the armature of a machine in the opposite direction to its flow when operating as a generator. The direction of rotation of the machine will be the same when running as a motor as when driven as a generator. This can be proved by applying the left hand or motor rule.

Motors and generators used for starting and lighting purposes are almost always four-pole machines. The field magents are made as compact as possible so as to concentrate the magnetic field. The magnets are supported by an iron case which completes the magnetic circuit and encloses all windings, brushes, and armature protecting them from dampness and dirt.

Due to the great variation in the speed at which the engine of a motor vehicle runs the voltage of a generator will necessarily vary. Most generators are designed to start charging the storage battery at a car speed of 8 or 10 miles per hour. As the speed is increased the voltage unless regulated in some manner will become excessive, resulting in burned-out light, excessive sparking at the commutator, and too high a charging rate. Therefore, some form of regulation

must be employed to keep the voltage or current supplied constant at the higher speed.

Several methods of accomplishing regulation are employed such as the compound wound, differential wound, and third brush control. These will be discussed in general and when any system differs it will be outlined under the description of that particular system.

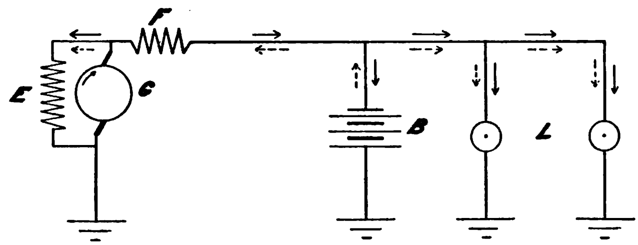


Fig. 214 — Lighting system without cut-out

Figure 214 shows a wiring diagram of a compound wound generator G connected to charge a storage battery B and furnish current for lights L. As long as the speed of the engine driving the generator is high enough the voltage at the generator will be greater than that of the battery causing current to flow as indicated by the heavy arrows. However, if the engine speed is reduced the voltage at the generator will fall off and the voltage of the battery will exceed that at the generator. This will cause current to flow in the direction indicated by the dotted arrows. The battery discharges through the generator causing it to run as a motor. To

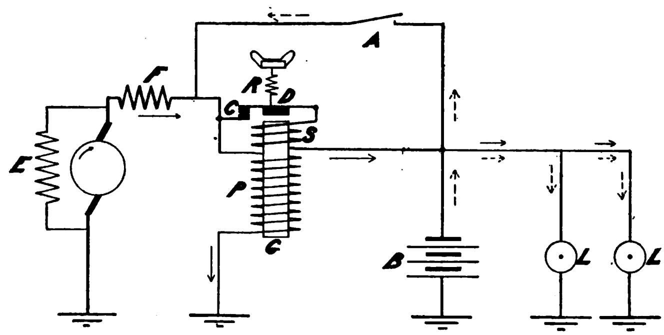


Fig. 215 — Starting and lighting system with cut-out

prevent the battery from discharging when the engine is slowed down or stopped an automatic cut-out is placed in the circuit.

Figure 215 shows a simple single-unit starting and lighting system with a cut-out. The current from the generator flows through the

potential coil P having a great many turns of fine wire, causing the soft iron core G to become magnetized. When the voltage at the generator becomes sufficient, enough current will be forced through the high resistance potential coil P to make the core G so strongly magnetic that the soft iron disc D is drawn to it against the action of the spring R. This causes the contact points C to close, the current flowing through the low resistance series coil S to the battery B and lights L. Only a little current continues to flow through P when the cut-out closes but the series coil S keeps the core G sufficiently magnetized to hold the cut-out closed. If the voltage at the generator falls off until it is less than that of the battery, current from the battery will start to flow in the opposite direction through the coil S. Coil P tends to keep the core G magnetized, though the current flowing through it has decreased, but coil S now tends to magnetize the core G in the opposite direction. This results in a weakening of the magnetic strength of G so that it cannot hold D against the pull of the spring R. The cut-out opens separating the contact points C and prevents the battery current from flowing back through the generator. The lights are now supplied by the battery until the voltage at the generator becomes great enough to close the cut-out. When the engine stops current is drawn from the battery by closing the switch A. The current flows through the generator in the opposite direction causing it to turn as a motor and crank the engine.

Third Brush Control

The Third Brush System of Control, while extremely simple in mechanical construction, is somewhat obscure in its electrical operation. This is due to the complex internal characteristic of the generator known as "Armature Reaction" which is fundamentally involved in the performance of the system.

In order to render the following description of the third brush system as clear as possible, the elementary theory of the electrical generator, and especially the subject of armature reaction will be reviewed briefly before explanation of the third brush system proper is taken up in detail.

Generation of electricity depends primarily upon three factors: the strength of the magnetic field, the amount of ampere turns of wire, the speed or mechanical force turning the armature. The voltage of electricity generated is always proportional to the product of these three factors.

Obviously then, if any one of these factors is increased or

decreased a corresponding increase or decrease will be produced in the generated voltage. On the other hand, if one of these factors is increased by any given amount, the voltage can still be kept at a constant value by decreasing one of the remaining factors by a proportional amount. This is the principle employed in the third brush control generator.

In automobile electrical systems, owing to the large ranges of speed, the variable factor of speed of rotation of the generator armature, the voltage change would be so great that disastrous results would prevail at high speeds unless some method of control was used.

Since the number of conductors on the armature cannot be changed while the machine is in operation the strength of the field must be changed to compensate for increases in the speed to keep the machine within the proper limits. This is the principle employed in the third brush control.

In the third brush system the governing feature is the armature reaction. Armature reaction is the name given to the effect produced upon the lines of magnetic force in the main field by the cross magnetizing force set up by the electrical current flowing through the coils of the armature.

With the main magnetic field established at full strength by the proper exciting current flowing through the field coils, the lines of magnetic force produced will leave the north pole piece, across the first air gap, through the armature, across the second air gap, enter the south pole piece, and return to the other starting point, in the north pole piece, through the frame of the machine. If no current is flowing through the armature coils the lines of force will pass in a straight line from the north pole piece direct to the other pole piece. The moment that the current begins to flow through the armature coils a secondary magnetic flux is set up in the armature core, and this " armature flux " will have a marked effect upon the main magnetic field according to the relative strength of the two component fields.

The armature flux is made of two components, one acting in direct opposition to the main field flux and tending to neutralize it. This effect can be neglected in the present discussion as it does not take an active part in the regulating duties of the third brush system.

The other component is at right angles to the main field flux and is of the utmost importance in bringing about the desired control of the generator output. It combines with the main field flux to produce a resulting field which is geometrically intermediate in

position and strength. The actual direction of the lines of force in the resulting field is proportional to the two forces.

The armature reaction component remains virtually unchanged through the speed range, while the main field component varies in value. After obtaining its initial large value it decreases with the speed to an ultimate value, which is only slightly larger than the armature reaction component.

The main field at a low speed is at its maximum strength and the consequent degrees of distortion of the resulting flux are therefore slight. As the speed increases the strength of the main field diminishes and the resulting flux is therefore increased.

Thus it is evident that although the armature reaction component is a virtually constant factor in any given machine, the effect of the armature reaction upon the position of the resultant or generating flux becomes increasingly great as the main field strength is cut down to compensate for the increasing speed.

The actual office performed by armature reaction in enabling the third brush system to control the output, is bringing about a redistribution of the voltages in the individual armature coils. As the result of this redistribution of the under coil voltages, the total voltage across the shunt field winding is altered; and thereupon through a series of changes, which will be explained in detail later, the desired regulation is accomplished. Due to the fact that the main field flux is shifted away from the third brush section of the armature as the speed rises the voltage across this section of the armature will be correspondingly reduced, because the coils in this section will be traveling through the weaker field. Since the greater part of the main field flux has been crowded into a section of the armature beyond the third brush, a relatively higher voltage will, under the same condition, be generated in that section. This higher voltage in the second quarter of the armature offsets the effect of the terminal voltage of the local voltage depression in the third brush section. In this way the terminal voltage of the generator can be maintained at a constant value throughout a wide speed range in spite of the reduction in the under coil voltages needed in one portion of the armature for regulating a shunt field voltage.

The third brush system exercises automatic control over the generator output under varying speed conditions by taking advantage of the effect of armature reaction to produce changes in the value of the voltage impressed across the shunt field windings. These changes in the field voltage set up corresponding changes in the field current. The current changes give rise to such modifications

of strength of the magnetic field as are needed to offset the effect of the speed variations, and thereby maintain the generator output at the required value.

The actual process of regulation from 1200 R. P. M. to 3500 R. P. M. is represented diagrammatically at successive stages in Fig. 216. The purpose of these diagrams is not to show the exact numerical value of the voltage, the current, and the magnetic flux that would exist in any particular machine under practical operating conditions but to point out the general inter-relationship between several factors, which effect the control of the generator output.

In Fig. 216A it will be noted that the lines of magnetic force extend in straight lines between the pole pieces. It is assumed that at the speed of 1200 R. P. M. that the field strength has reached its maximum and the generator is therefore able to charge the battery to a moderate rate. In this condition the regulating flux of the Third Brush has not come into effect, therefore the machine operates as a standard shunt wound generator at low speeds, and the characteristic of its output below this speed is the same as with a straight shunt wound machine, that is as the speed increases the output increases.

Figure 216B represents the same machine operating at 1800 R. P. M. The armature reaction has begun to cause a shifting of the lines of force, the distortion is slight since the armature reaction has increased somewhat due to the increasing armature current, the main field is still much stronger than the armature cross field, the effect is sufficient, however, to prevent the field voltage from rising above the value of seven volts, which is attained at 1200 R. P. M. The field strength has been kept constant but the speed has risen. As a consequence a slight rise has taken place in the terminal voltage, which resulted in a corresponding increase of ampere output. We assume now that the generator has reached its maximum value of output. It will maintain this maximum value of output for *each* increase in speed for certain limits.

Figure 216C shows the generator conditions when operating at 2200 R. P. M. The armature reaction has brought about a pronounced distortion of the magnetic field. This results in the voltage between the negative brush and the third brush dropping in accordance with the amount of distortion. Due to this voltage drop the field strength becomes weaker and the magnetic field consequently weaker. This is offset, however, by the increased speed and therefore the voltage between the main brushes is of the same value as at 1800 R. P. M. therefore the output of the machine is

the same at these speeds and practically the same at all the intermediate speeds.

Figure 216D shows the generator conditions when operating at 3500 R. P. M. At this speed the voltage across the shunt field winding has dropped to four volts due to the very decided distortion

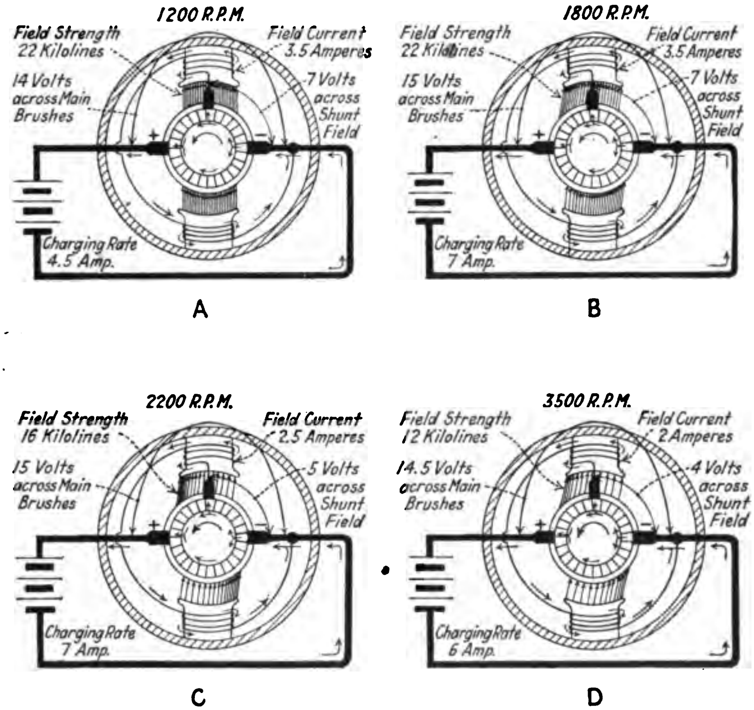


Fig. 216—Third Brush Control

of the lines of force in the magnetic field. This materially reduces the field strength, which in turn reduces the number of lines of force flowing between the poles. This reduction in the field strength has been proportionately greater than the increase in the armature speed, therefore the terminal voltage has been decreased and consequently the charging rate has been reduced.

As the speed increases above this point the armature reaction will cause a greater distortion of the lines of force in the magnetic field and the voltage between the negative brush and third brush will materially decrease thereby reducing the field strength, which will diminish the voltage between the main brushes, which in turn will diminish the generator output.

From the foregoing explanation of the construction and operation of the third brush system, it will be seen that a generator equipped with this method of control contains within itself all the elements which are instrumental in controlling its output. The curve of output of this machine therefore will be from zero to its maximum output, then tapering off as the speed increases. As the machine operates practically as a straight shunt wound machine until it reaches its peak of output, the rise in output will be very rapid and the amount of output that drops off after it reaches its peak will depend upon its construction, which for each individual machine will have different armature reaction. Another value of this machine is that by changing the location of the third brush, it will change the characteristics of the machine in relation to its output. For it will be readily seen that by moving the brush in either direction it will bear a different relationship to the armature reaction and therefore the voltage between the third brush and the negative brush will be changed, which will change the field strength and consequently the output. The feature of the gradually tapering charging rate is especially desirable in automobile equipment, because it affords an excellent means for preventing the battery from receiving too great a charge in cases where the car is used for long distance high speed touring.

North East

The North East system consists of a single motor-generator; which furnishes current for charging the storage battery, lights, and the ignition; and cranks the engine when starting. The machine is a four pole outfit with a series field and shunt winding for third brush control. It is driven by silent chain from the crank shaft ordinarily at three times engine speed.

Figure 217 shows the internal wiring of the North East motor-generator installed on the Dodge car. The shunt field is shown in light lines and the series field is shown in heavy lines. A fuse is provided in the shunt field as a protection to the generator and cut-out. One end of the shunt field winding is attached to the third brush and the other end is attached to ground through the fuse.

There are two sets of series windings. One is attached to ground and the other end to the negative brush. The other series winding has one end attached to the positive brush and the other end attached to the generator terminal.

The third brush regulation is the same as previously explained. In addition to this the series field acts as a bucking field having a demagnetizing effect upon the strength of the field created by the shunt winding. The charging rate starts at approximately 10 miles per hour of the car speed and the maximum charging rate of six amperes is reached at a speed of about seventeen miles per

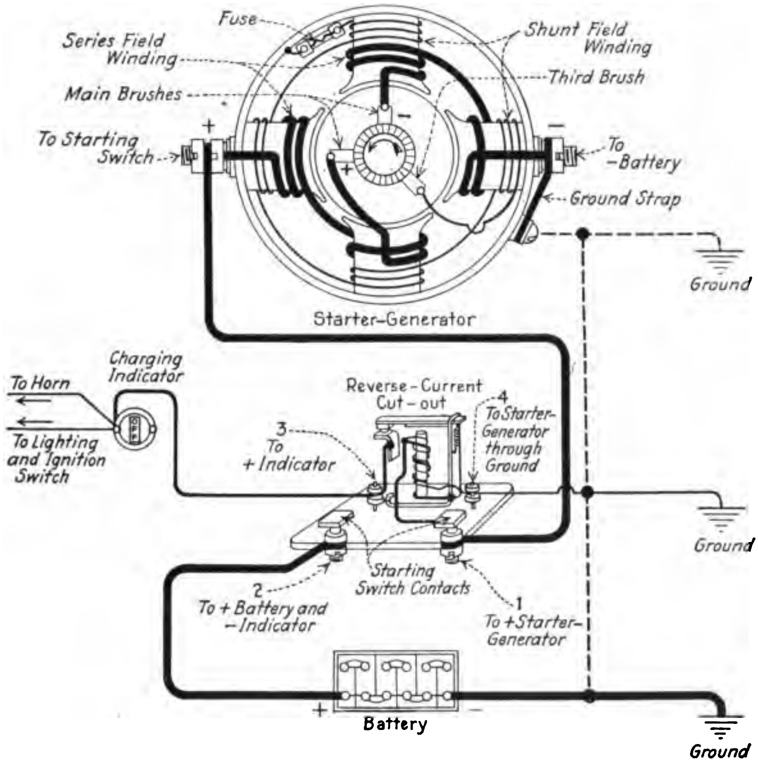


Fig. 217 — North East Starting & Lighting Systems

hour. At extremely high speeds the charging rate falls off becoming as low as three amperes. These charging rates may appear to be low but it must be borne in mind that this is a twelve volt system.

To increase the charging rate the third brush is moved in the direction of the armature rotation. This setting should never be changed unless the battery is habitually low or the charging rate too high. Too high a charging rate is indicated by the battery requiring the addition of water too frequently.

The cut-out on this machine is of the usual two winding type, having a potential and a series winding. The cut-out is mounted in the foot starting switch, the reason for this being that when the starting motor switch is closed the current will not pass through the cut-out.

When operating as a starting motor the current is led from the battery to the terminal *2* and crosses the switch contacts which are connected by a heavy copper bar. Terminal *1* of the switch is connected to the positive terminal of the generator. The current flows internally through one series field to the positive brush through the armature coils to the negative brush through the other series field to ground and then back to the battery. In this way the machine operates as a series starting motor giving the high torque necessary to crank the engine. This heavy current does not pass through the ammeter or cut-out.

Figure 218 shows the complete wiring of the North East single unit system of starting and lighting on the Dodge car.

The ammeter used with this system does not show the amount of current passing into the battery but reads " charge." When the speed is reduced sufficiently the cut-out opens and the battery furnishes whatever current is desired and the ammeter reads " discharge."

Bosch

Bosch starting and lighting system consists of two units: the generator, which is a four pole shunt wound machine of the third brush regulation; and the starting motor, which is a four pole series wound machine.

The generator (Fig. 219) furnishes the current for charging the storage battery, for operating the lights and for ignition. The generators are made in two sizes, four and five inch machines. The four inch is designed to be driven at 1½ times engine speed and the five inch at engine sped. Operation of the third brush control is identical with that explained previously. Figure 220 shows the brush construction and it will be noted that the third brush is movable for adjustment of the output in accordance with conditions required. In this design it is necessary to remove the commutator cover in order to change the setting of the third brush. This is done for the special reason that the settings are made at the factory in accordance with conditions under which the generator is to operate.

The cut-out is mounted on the generator and is of the two winding construction, having a potential and series winding. The po-

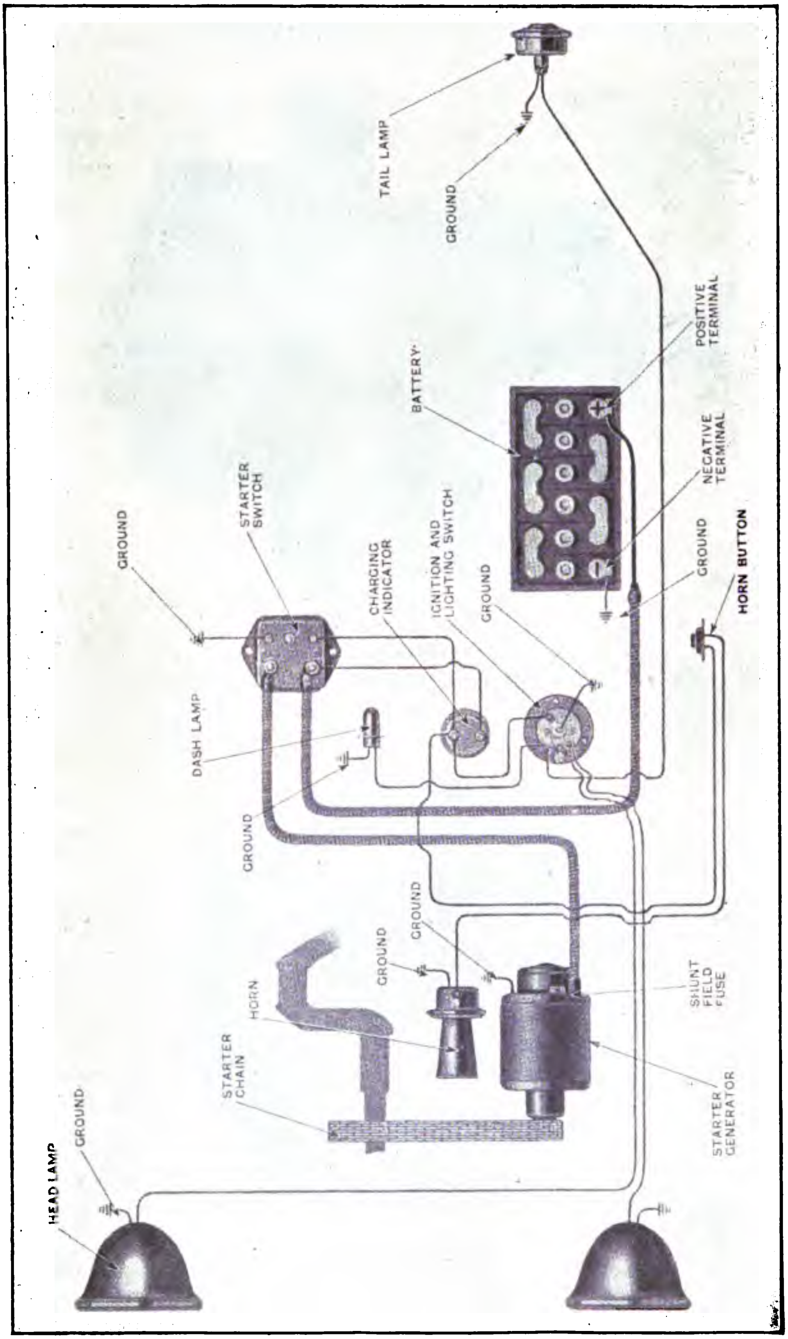


Fig. 218 — External wiring on Dodge car

tential winding is designed so that when the generator is operating at a speed sufficient to have the voltage at approximately 6.5 volts

Fig. 219 — Bosch generator

it will exert sufficient pull on the armature of the cut-out to close the circuit, which permits the current to flow through the series

Fig. 220 — Brushs

winding to the battery. When the speed of the generator falls below a certain point at which the voltage generated is not sufficient

to charge the battery, the cut-out opens and disconnects the storage battery from the generator thereby limiting the possibility of the battery discharging through the generator.

The fuse is placed in the field circuit to protect the instrument in case of short-circuit or in case the battery lead becomes disconnected. This fuse although connected in the field circuit is not only a protection to the field windings but also to the armature and windings on the cut-out.

This is a one wire or grounded system having one of its main brushes internally connected to the ground, therefore the only wire leading from the generator is the main lead of the battery, as there are no controls or regulating devices other than the controls and cut-out incorporated in the instrument. This gives a very satisfactory and simple wiring for installation.

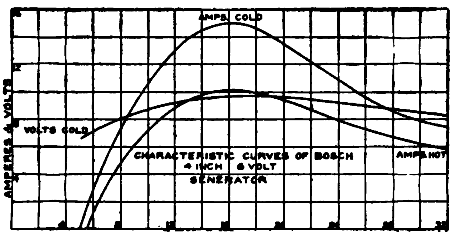


Fig. 221 — Output curve

Figure 221 shows. the output curve of the four inch machine. It will be noted that there are two output curves given, one termed " amperes cold " and the other termed " amperes hot." This machine is designed so that it will stand excessive heat without damage to the instrument, but when heat is introduced into the electrical circuits it increases the resistance and therefore the output is less in proportion to the degree of heat. These two curves are given for the extreme conditions of the instrument. It must therefore be borne in mind that a depreciation in the output is not always due to defective operation of the instrument, but is often due to the heat of the generator at that particular time. After the motor has been run continuously for an indefinite period the heat due to certain electrical conditions will cause depreciation in the output. This is true with all electrical apparatus.

The starting motor Fig. 222 is of the series wound type and is also designed in two sizes, the four inch and the five inch. It employs a bendix drive for meshing the pinion on the starting motor with the teeth on the flywheel. The operation of the bendix drive

is entirely automatic in its engagement and disengagement of the pinion on the starting motor and the gears on the flywheel.

The collar (Fig. 223) next to the armature winding is fixed rigidly to the shaft with a bolt. The balance of the parts of the bendix drive are free from the shaft and collar except by its con-

Fig. 222 — Bosch starter

nection through the spring. The spring is attached to this collar and also to the shaft carrying the worm gear. This shaft is not connected to the shaft of the starting motor but only uses it as a bearing. The pinion has a female thread cut on its inside circumference, which meshes with the worm.

Fig. 223 — Bendix drive

When current is first passed into the starting motor it immediately starts at full speed and operates under full power. This turning effect is transmitted through the collar and spring to the shaft carrying the worm. The pinion due to its inertia of rest and its unbalanced weight travels along the shaft and engages with the teeth of the flywheel. A slight turning effect is given to the pinion so that its teeth do not travel in a straight line. This slight turning effect off-sets the possibility of the teeth not meshing properly.

As soon as the teeth are engaged the torque of the starting motor is transmitted through the spring to the worm shaft and pinion. The pinion transmits the torque to the teeth on the flywheel and cranks the engine. The spring acts as a cushion after the gears are meshed winding up slightly to offset the sudden strain which would otherwise be placed on the starting motor. This permits the starting motor to get a breakaway more easily.

As soon as the engine fires the increased speed transmitted to the pinion causes it to travel back on the worm shaft

Fig. 224 — Bosch switch

and disengage the gears. The action of the engagement and disengagement is therefore purely automatic by mechanical construction.

The Bosch switch used with this lighting system Fig. 224 is a combination switch and ammeter set having a light placed directly between the two. A lock switch is incorporated, which by the turning of the key controls the ignition. This lock will also lock the lever controlling the lights in any desired position. The switch is designed for bright or dim headlights in accordance with the location of the switch handle.

The wiring of these systems is very simple, being a single wire system. A typical wiring diagram is shown in Fig. 225. It is usually advantageous to ground one side of the battery and connect the other side of the battery to the starting switch by heavy cable. From this terminal on the starting switch a light wire is connected to the ammeter. The other side of the ammeter is connected to the switch and also the generator. The ammeter connected in this way shows the amount of current going into the battery but does not show the amount of current which the generator may be charging for the lighting or ignition apparatus. The other side

of the starting switch is connected to the starting motor. The lamps and ignition are connected to the switch in the usual manner.

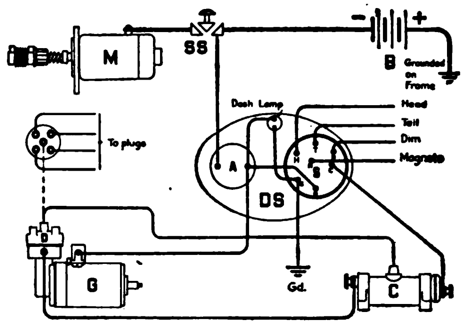


Fig. 225 — Wiring diagram

Dyneto

Dyneto single unit motor-generator Fig. 226 is designed for twelve volts and is operated at about three times engine speed. A single switch is used to control the operation as a generator or starting motor. In starting, the switch is moved to the position " start " and left in this position unless the battery is fully charged or the car is to be used for long and fast runs, in which case the switch lever should be moved to " neutral " and left there.

Fig. 226 — Motor generator

With the switch in the " start " position the motor-generator will operate as a motor and crank the engine at about 125 R. P. M. After the engine begins to operate under its own power, at speeds above seven or eight miles per hour, the machine automatically operates as a generator and charges the battery. At all speeds below seven miles per hour it operates as a motor. The power available from the motor increases as the speed is diminished and at very low speed prevents the engine from stalling. There is no cut-out used with this system so that when the generator voltage falls below the voltage of the battery, the battery will discharge through the generator.

The regulation of the generator is accomplished by third brush control and the differential effect of the series winding. As a starting motor it operates as a compound wound machine.

Figure 227 shows the internal and external wiring of this system. The negative side of the battery is connected to the negative terminal of the motor-generator. The positive side is connected to

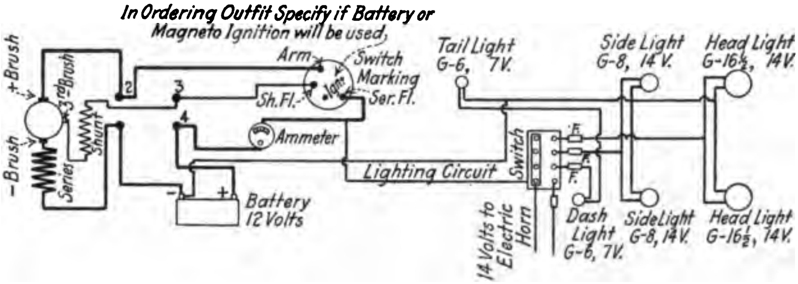


Fig. 227 — Wiring diagram

the switch. The positive terminal of the generator is connected to the switch. The terminal of the generator connected to the shunt field winding is also connected to the switch. The wiring of the lighting circuit is the same as usually employed with ungrounded system.

The Dyneto two unit system consists of a shunt wound generator with third brush control and a series type of starting motor. The generator operation and control is the same as that previously explained under third brush regulation. The cut-out is either placed on the generator or separate and mounted on the dash.

The starting motor is of the usual series wound type employing the bendix drive for engagement and disengagement of the gears.

Leece-Neville

The Leece-Neville starting and lighting system consists of two units, a shunt wound four-pole generator and a series wound motor. The generator furnishes current for charging the storage battery, lights, and ignition and the motor cranks the engine drawing current from the storage battery.

The generator, running at approximately engine speed, is driven by a chain from the crank shaft. Third brush regulation is used which has already been explained. An automatic cut-out is provided to prevent the battery from discharging through the generator at low engine speeds and is of the usual construction.

Figure 228 shows the internal wiring of the generator and circuit breaker or cut-out. In the grounded system the brush connected to *A–2* is internally grounded and only one cable comes from the cut-out. The charging rate is controlled by the position of the third brush. The shunt field is protected by a 10-ampere fuse.

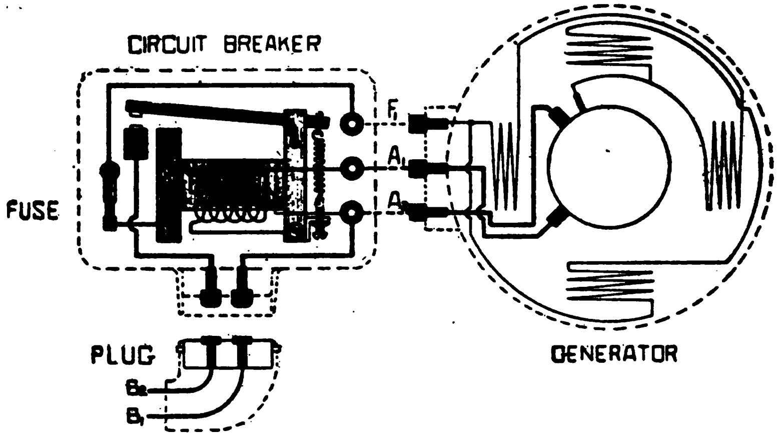


Fig. 228 — Internal wiring of Leece-Neville

The motor is attached to the crank case and drives the flywheel of the engine through the gear teeth cut in its circumference by means of a small pinion directly driven by the motor armature shaft.

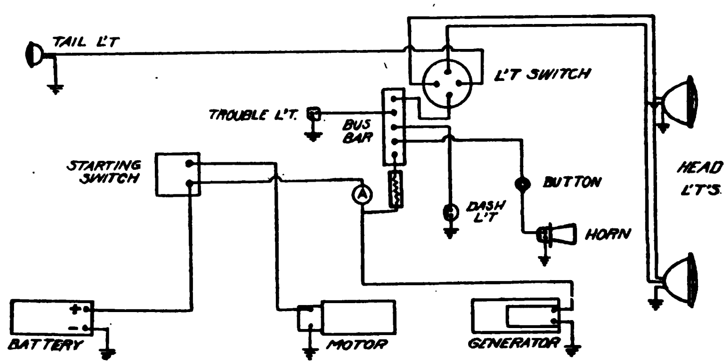


Fig. 229 — Wiring on White

Figure 229 shows the complete wiring of the starting and lighting system installed on the Staff Observation Car. The motor is supplied with current from the storage battery when the starting switch, which is located on the floor boards of the car, is closed. The

generator charges the battery and supplies the lights with current when the cut-out is closed and the battery supplies the lights when the cut-out opens. A circuit-breaker is provided in the lighting circuit which takes the place of fuses opening when there is a ground on the line.

Bijur

The Bijur starting and lighting system is of the two unit type. The generators are made either for the third brush control or voltage regulation. The starting motors are of the ordinary series wound type.

Figure 230 is an internal wiring diagram showing all circuits except the connections to the lights. A cut-out is provided which operates in the usual manner the storage battery furnishing current when the cut-out is open.

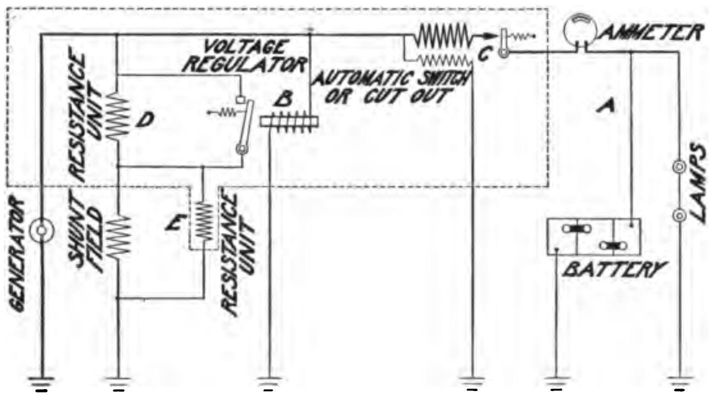


Fig. 230 — Internal wiring of Bijur

The voltage regulator is of the vibrating variable resistance type. The voltage regulating unit as shown in Fig. 230 at *B* consists of a core having a single winding connected in parallel with the armature. The current in the winding and the resulting magnetic pull of the core will depend upon the pressure developed by the generator. Opposite one end of the core is a vibrating armature which is spring retracted from the core. When the armature is retracted it makes contact so that there is a by-pass around the resistance *D* which is in series with the field winding of the generator. With the vibrating armature in this position the shunt field winding receives the full pressure developed by the generator. With increasing generator speed the voltage increases until the armature develops 7.75 volts, and at this electrical pressure the regulator begins to

function and will maintain this voltage across the generator brushes at all higher speeds.

With increasing generator speed the voltage will tend to rise above 7.75. However, if this value is exceeded by a very small amount, the increased pull on the armature of the regulating unit will overcome the spring pull and the armature will be drawn towards the core, thus opening the contacts and inserting the resistance *D* in the generator field circuit. The added resistance in the field circuit decreases the exciting current in the field winding and the voltage developed by the armature tends to drop below the normal value. If the voltage drops slightly below the normal the pull of the spring on the regulator armature predominates and this armature moves away from the core and closes the cut-out which short-circuits the resistance and permits the exciting field current to increase. This cycle of operations is repeated at rapid intervals and maintains the generator voltage constant at all speeds above the critical value at which it develops 7.75 volts with the resistance cut out of the field circuit.

The rapidity of vibration depends to a large extent upon speed, but in general the regulator armature vibrates at the rate of one hundred to one hundred and fifty times per second. The actual voltage developed by the generator is made up of a series of very small impulses the mean value of which is 7.75 volts. This is the constant value for which the regulator is adjusted.

It is obvious that increasing the tension of the regulator spring will increase the constant voltage which the generator will maintain. Under no circumstances should the regulator spring tension be increased in an attempt to have the generator charge at a higher rate at low speed. The generator cannot begin to charge until the cut-out has closed and the closing of the cut-out is independent of the action of the regulator. This cut-out closes after the generator reaches a speed at which it develops 6.5 volts, and no adjustment of the regulator or cut-out can change the charging rate at low speed. Increasing the tension of the regulator spring so that the generator will develop a constant voltage in excess of 7.75 volts will result in excessive current to the battery overcharging it or causing the generator to overheat with the possibility of burning it out.

In addition to the resistance in series with the shunt field winding there is another resistance *E* which is connected in parallel with the field winding. The function of this resistance is to absorb the field energy when the regulator contacts are opened and reduce sparking at the contacts.

The third brush control generator is of the usual construction and regulation explained under the third brush control. The cut-out is incorporated in the machine and is of the usual two winding construction.

The starting motor is a series wound four pole machine designed for operation on a six volt circuit and is equipped with a Bijur make of automatic gear shifting device mounted on its armature shaft for transmitting power from the starting motor to the flywheel.

The instant the starting switch is closed the current from the battery passes direct to the starting motor and the motor begins to operate under full power. The gear shifting device, mounted on the threaded end of the armature shaft by virtue of its inertia of rest, is forced to travel on the rotating shaft automatically meshing with it and transmitting power to the flywheel teeth, and thus cranking the engine. The instant that the engine begins firing, the increased speed given to the pinion throws the gear shifting device out of mesh with the teeth on the flywheel. Figure 231 shows the construction of the gear shifting device.

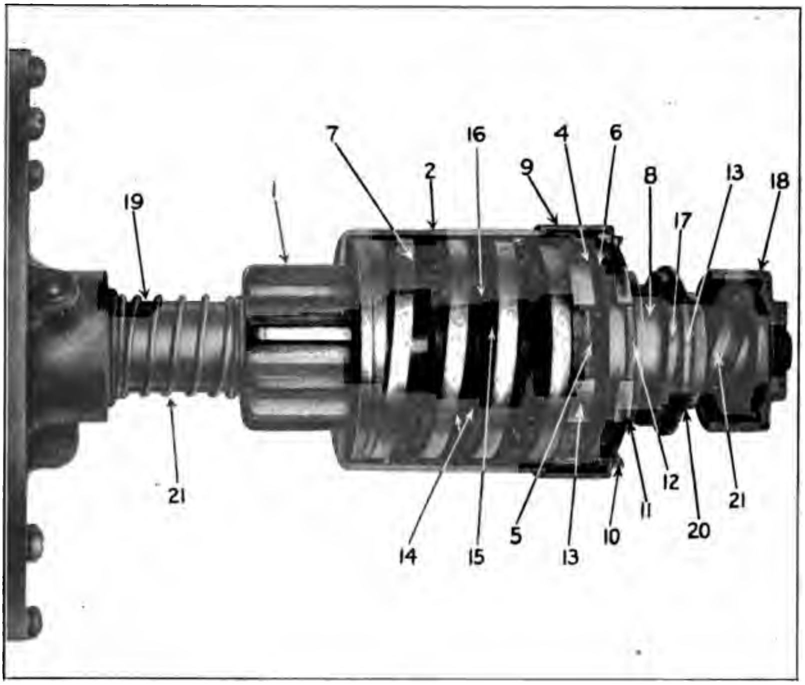


Fig. 231 — Bijur gear shift

The pinion *1* is free to turn on armature shaft *21* and is driven by notches on the barrel *2* registering with the pinion teeth. This barrel has six slots cut in its outer end in which the notched clutch plate *3* registers. The cork clutch *4* is held in place *3* by a notched retainer *5* and its left-hand face can slip slightly against the smooth ground face *6* of the flanged threaded nut whenever the torque exceeds the friction hold between the cork and the steel faces, this holding force being set up by the initially compressed spring *7*. Power is thus transmitted in the working position from the shaft to the flanged nut assembly *8*, thence to the cork clutch *4*, the clutch retainer *5*, inner clutch plate *3*, barrel *2*, and thus to the pinion *1*.

The barrel cover *9* fits into and over the notch barrel *2* and effects closure of the shift, being held in place by a spring cover lock *10*.

In addition to the cork clutch there is a fixed clutch *11* mounted on the back face of the flange nut and shown as a notched plate. This is held against the flange by means of the dished spring washer *12* sleeve *17*, washer *13* and wire lock spring *20*. It is called "fixed" because the torque necessary to cause it to slip is constant irrespective of the position of the flanged nut.

Normal engagement is effected by depressing the starting switch button, causing the shaft to rotate within the threaded flanged nut *8*, the inertia of which causes a difference in speed between the shaft and the nut with the result that the nut travels along the threaded armature shaft and urges the entire assembly of barrel and pinion through the spring *7* into mesh. The spring *7* rests at its right hand against a flanged plate riveted to the pinion; on its left hand against the inner clutch plate *3*. When the flange nut *8* gets to the end of its stroke, it first compresses a pair of dished washers (shown at *14*), through a pair of thrust bearing washers *15* and *16*. It is the combined object of the dished washers, as well as the clutch, to take up the shock of starting. The helical spring *7* plays little, if any, role in this. Of course, when the clutch plate *3* strikes the washer *16* the axial pressure on the clutch face rises enormously; that is to say, the clutch becomes self-tightening to meet the load applied.

Disengagement is caused by the over-riding speed of the pinion barrel and not with respect to the revolving armature shaft. Shock of disengagement is absorbed by the action of the cushion spring *17* which is compressed by the impact against the back of nut *18*.

The purpose of clutch plate *11* is to get sufficient initial clutch tension added to the cork clutch *4* to avoid slippage when a "butt" occurs.

Whenever a pinion tooth " butts," that is, strikes the corresponding end of the flywheel tooth, the following action takes place to obviate same: The pinion is now kept from entering the flywheel teeth and the traveling nut compresses the spring *7* and urges the barrel *2* forward along the teeth of the pinion. Finally, the clutch plate *3* strikes the washer *16* which tightens the clutch plate *3* and causes the flange nut assembly *8* to turn with the shaft. The barrel *2* is therefore turned by the notched clutch plate *3* and in turn transmits its rotative effect to the pinion *1*, releasing the " butting " pinion tooth from its interference. The instant this happens the spring *7* having been by the previous action greatly compressed, snaps the " butted " tooth into mesh with the flywheel teeth and normal cranking takes place.

The function of the weak spring *19* is to prevent " ticking in " of the barrel and pinion especially when the car is running down hill. The action therefore of this gear shifting device is purely automatic in its engagement and disengagement of the gears.

Delco

The Delco starting and lighting system as used on the Cadillac car consists of a single unit motor-generator which furnishes the current for charging the storage battery, the lights, and ignition system and also runs as a motor cranking the engine. The motor-generator is a four pole machine with separate sets of field and armature windings necessitating two commutators being used which are located at opposite ends of the armature. The motor is series wound and the generator shunt wound. The motor-generator, when acting as a generator, is driven at engine speeds by the fan shaft which in turn is driven by a silent chain from the cam shaft at the front end of the engine. To prevent the voltage of the current generated from rising too high when the engine is running at high speeds the third brush system of current regulation is employed which has been explained.

When acting as a motor the sole function of the motor-generator is to crank the engine. In starting first the operator pushes down the ignition lever on the combination switch. This closes the ignition circuit and the circuit between the storage battery and the generator windings on the motor-generator causing the armature to revolve slowly.

A ratchet clutch (Fig. 232) in the front end of the generator allows the armature to rotate ahead of the driving shaft. The clicking noise that is heard when the ignition switch is turned on comes from this clutch.

As the starter button is pushed down it first causes the starter gears to mesh with the teeth on the flywheel. The proper meshing of the gears is made easy by the slow rotation of the armature which begins as soon as the ignition is turned on. As the starter button is pushed further down the circuit between the storage battery and the generator windings of the motor-generator is broken at X (Fig. 233). As the movement of the starter button is completed the circuit is closed between the storage battery and the motor windings on the motor-generator by the motor brushes coming in contact with the commutator, causing it to act as a powerful electric motor, which rapidly cranks the engine.

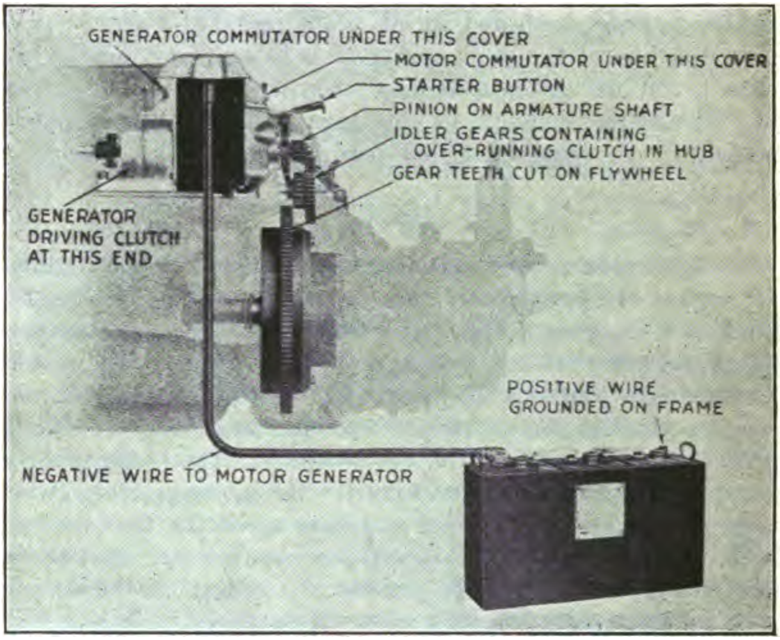


Fig. 232 — Installation of Delco on Cadillac

The gear ratio between the armature shaft and the crank shaft being approximately 25 to 1, the armature would be driven at an excessively high rate of speed after starting the engine before the operator let the starter button back, if it were not for an over-running clutch in the hub of the idler gears between the flywheel and the armature shaft. The electric motor cranks the engine through this clutch but after the engine has started and begins to run faster than the electric motor the clutch releases.

The starter button is let up as soon as the engine is running under its own power. The first movement of the button breaks the circuit

between the electric motor and the storage battery by lifting the brushes from the commutator. A further movement causes the starter gears to slide out of mesh and the release of the button completes the circuit between the generator and the storage battery at *X* which was broken when the starter button was pushed down. The engine running and the circuit being closed between the storage battery and the generator windings of the motor-generator the generation of current begins.

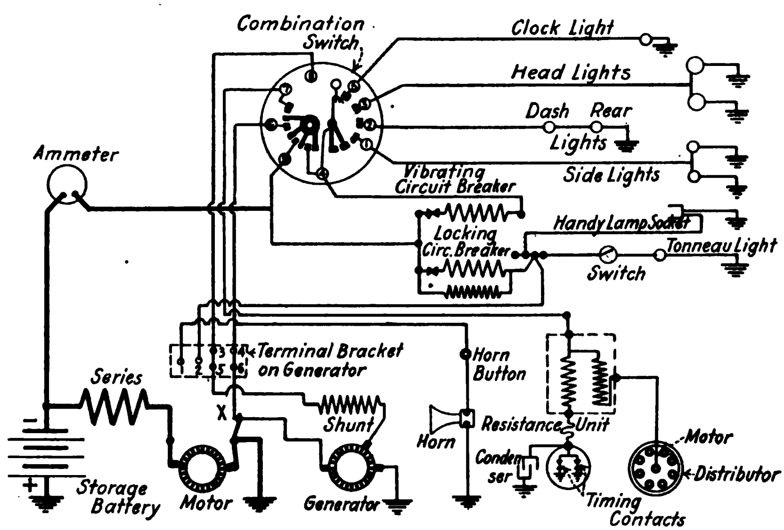


Fig. 233 — Internal wiring of Delco

Figure 233 is a complete wiring diagram of the starting, lighting, and ignition system used on the Cadillac car. Circuit breakers take the place of fuses in the lighting circuit and no cut-out is provided. When the generator voltage is less than the voltage of the battery, current will flow back through the generator. The amount flowing is somewhat less than that flowing through it when first starting. This is so little that it is practically negligible (about 5 amperes). The circuit between the generator and battery is broken when the ignition switch is thrown off.

A Delco generator with a single set of windings is installed on some Standardized B trucks. It furnishes current for lights and ignition but does not crank the engine. No cut-out is provided except the ignition switch which breaks the circuit between generator and battery when in the " off " position. When thrown to the " on " position the generator will turn slowly as a motor until the engine is started causing a " clicking " noise due to the over-run-

ning clutch which permits it to turn free of the engine. As in the system on the Cadillac car very little current is used in this way.

Simms-Huff

The Simms-Huff starting and lighting system used on the Maxwell car consists of a single unit motor-generator with a switch, a combined cut-out and relay switch, battery, and other accessories necessary.

Fig. 234 — Motor generator

Figure 234 is a six pole compound wound machine, the series winding of which is connected in such a way that when used as a motor the series and shunt windings reinforce each other so as to give a maximum starting torque. When operated as generator the shunt winding is opposed by the series field winding so as to assist same in limiting the current output at high speeds.

The series winding consists of three coils of heavy wire mounted on three of the pole shoes, the inner end of each coil is grounded by connecting to each pole separately; the outer end of each coil is connected to each of the negative brush holders. The shunt field is composed of three large coils and three small coils, each wound with many turns of small wire. The small coils are mounted on the pole shoes over the series winding. The large coils are mounted on the pole shoes that do not carry the series winding. All six shunt coils are connected in series. One end of the shunt field is grounded by connecting to one pole and the other end is connected to the shunt field terminal on the side of the machine.

The cut-out used with this system is mounted in a control box and is of the usual two winding construction.

The Simms system used on the 1920 Maxwell was of the two unit type, using a standard shunt wound third brush control gener-

ator with cut-out mounted on the machine. The starting motor is of the series wound type having six poles instead of four as used by many other manufacturers. Otherwise the system is identical with the usual practice of starting motors of this construction.

Atwater Kent

The Atwater Kent starting and lighting equipment is a six volt two unit system. The generator is shunt wound with the third

Fig. 235 — Generator

brush control. The regulation of current output is obtained by connecting the field winding between one of the main brushes and the narrow third brush located between the two main brushes. As

Fig. 236 — Starter

the speed of the generator increases the distortion of the magnetic field with respect to the third brush controls the strength of the field winding. The reduction in the field prevents an increase in the generator voltage which would othewise result from the

increased speed. The charging current is therefore kept within limits, which will enable the battery to regulate the voltage of the system.

The generator Fig. 235 is equipped with a cut-out mounted on the generator frame, which acts as a safety device to prevent the battery from discharging through the generator at low speeds. It connects the circuit between the generator and the rest of the system when the generator speed is such that its voltage is sufficient for charging the battery. It automatically disconnects the generator when the speed falls below this rate.

The starting motor Fig. 236 is a series wound high speed motor. It employs a standard bendix drive, which automatically engages the pinion with the teeth cut on the flywheel when the current is first passed through the starting motor.

Westinghouse

The Westinghouse two unit outfit consists of a generator employing third brush control and a series wound starting motor and is constructed for six volt system.

The generator is a four pole machine having a shunt winding connected between the negative brush and the third brush. In this field winding there is connected a five ampere fuse as a protection to the lighting outfit in case of short-circuits or a wire being disconnected from the battery. The cut-out is separate from the generator and is of the usual two winding construction.

The starting motor is series wound having four poles. Two sets of series windings are used. One end of these is internally grounded and the other ends are connected to the positive brushes. The negative brushes are connected to the terminal on the motor. The operation of this starting motor is identical with all other starting motors of the series wound type employing the bendix drive.

Figure 237 show the internal and external wiring diagram of these systems and it will be noted that it is necessary to have a proper ground connection for the cut-out otherwise it cannot get its proper return to the generator for operation of the shunt winding.

Ford Magneto

This magneto may be classified as a high frequency alternating current magneto. It serves merely as a source of primary current for the vibrating coil type of ignition system and for supplying current for lights.

The construction is as shown in Fig. 238. The sixteen armature coils are stationary and are wound around cores of soft iron which are supported on an iron frame. An equal number of permanent magnets of the horseshoe type are secured to a nonmagnetic ring attached to the flywheel and revolve with it.

The north poles of two adjacent magnets are joined together and likewise the next pair of south poles. When a pair of north poles are in front of the core of one coil, the magnetic flux will flow in

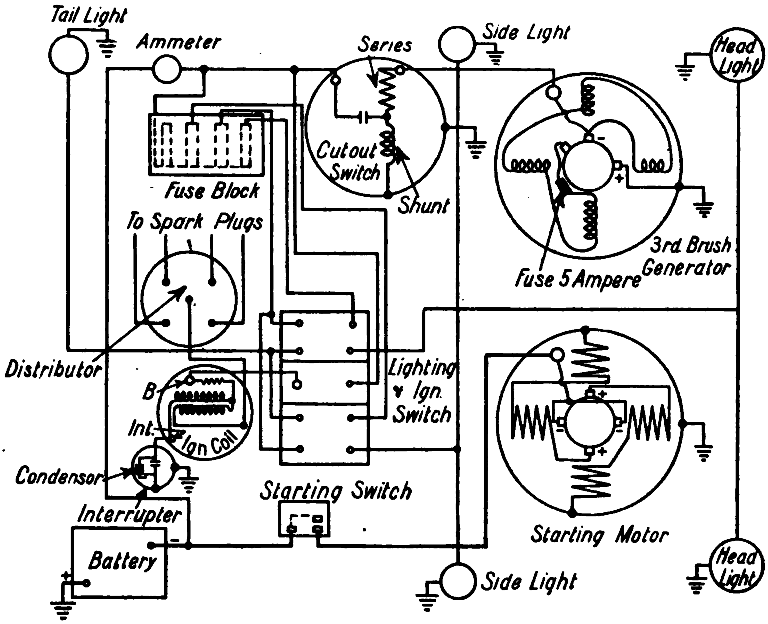


Fig. 237 — Wiring diagram

through this core across the supporting frame and out through the cores of the adjacent coils to the south poles of the magnets. When the flywheel makes $\frac{1}{16}$ of a revolution the coil cores which were opposite the north poles of the magnets will be opposite the south poles causing a complete reversal of magnetic flux to take place in every coil core. This induces a voltage causing a current to flow in each of the coils. The coils are connected in series and one end is grounded. The other end is connected to the insulated binding post on the outside of the flywheel housing from which the current supply is drawn. Hence, as the flywheel revolves an alternating current of high frequency will be obtained from this magneto. This current is used for exciting the primary of the ignition system as well as for lighting purposes.

As there is no regulation in the system to control the voltage or output, the current generated will depend directly upon the speed of the engine. Therefore, the faster the engine goes the better will be the results obtained from the ignition system and likewise the

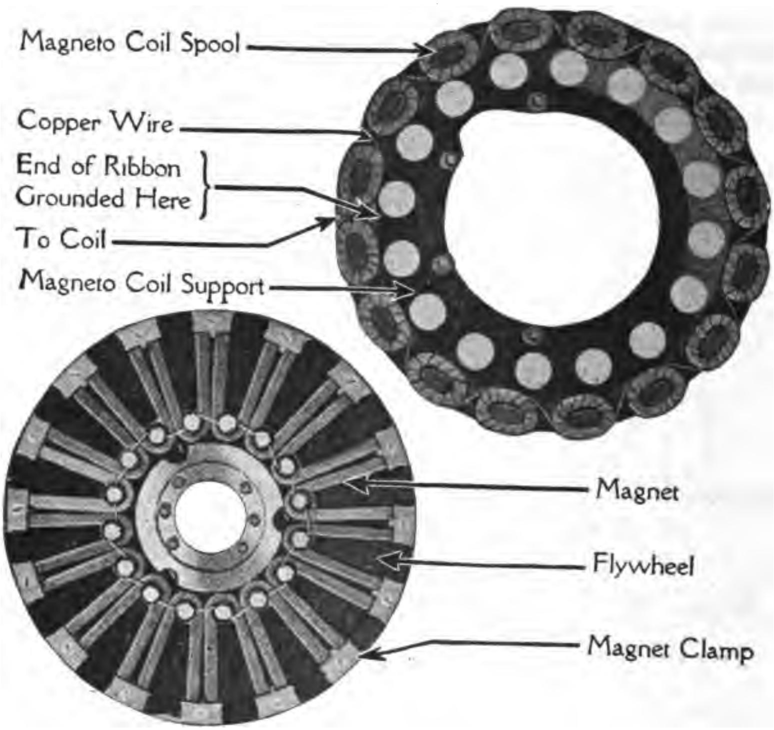


Fig. 238 — Ford magneto

intensity of the lights will increase. It will often be noticed on Ford cars that there is a considerable variation in the intensity of the lights. Since the current generated is alternating a storage battery cannot be connected in the line to overcome these difficulties.

CHAPTER XXI

POWER TRANSMISSION

To transmit the power developed by the engine to the wheels of a motor-propelled vehicle certain parts are necessary because of the conditions under which a motor vehicle is operated. The application of the engine power to the driving wheels through these parts is called "power transmission" and their arrangement will be discussed in this chapter.

The units composing the power-transmission system are practically the same on all modern trucks and motor cars but their arrangement varies, depending upon the method of drive and the type of units used. The following units will be found on all modern machines; a clutch, a transmission or gear set, drive shafts, universal joints, differentials, and axles extending to the driven members (chain sprockets or wheels).

When the power is transmitted to the rear wheels only, the arrangement of the parts will be as shown in Fig. 239. This arrangement is typical of light cars of two wheel drive, except the Ford in which the parts are arranged as shown in Fig. 241. In Figure 239 the power is transmitted from the engine through the clutch *A* to the transmission *B* then through the drive shaft *C* with universal joints *D* to the differential. The differential transmits the power to the rear wheels.

If the engine, clutch, and transmission are not a unit power plant, that is, if they are not contained in the same housing it will be necessary to have an arrangement as shown in Fig. 240. The only difference is that a shaft *E* and universal joints *F* (sometimes called alignment joints) are between the clutch and transmission.

Because of the special type of transmission used on the Ford the clutch and transmission are reversed but in all other respects it is identical in its system of power transmission.

The location and arrangement of the units of power transmission on a chain drive apparatus differs as show in Fig. 242. The differential is now contained in the same housing as the transmission. There is no drive shaft with universal joints between these parts. The power is transmitted in the usual way to the transmission and then direct to the differential. From the differential it is transmitted by jack shafts *G* to the sprockets *H* and to the wheel sprockets *I* by chain *J*.

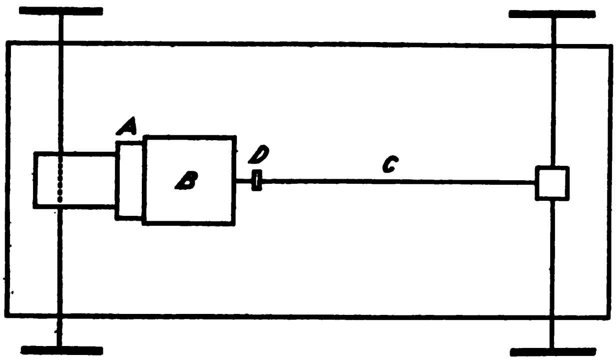


Fig. 239

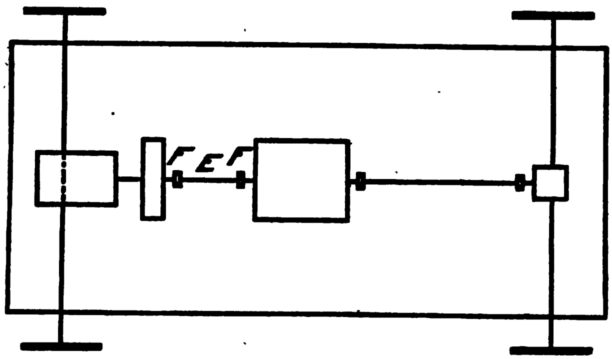


Fig. 240

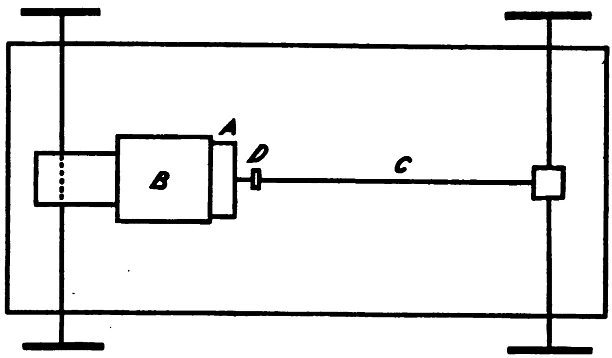


Fig. 241

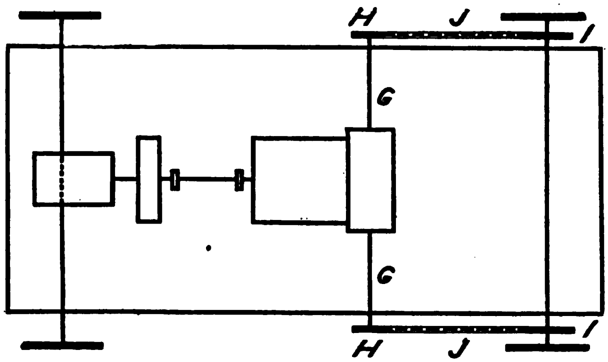


Fig. 242

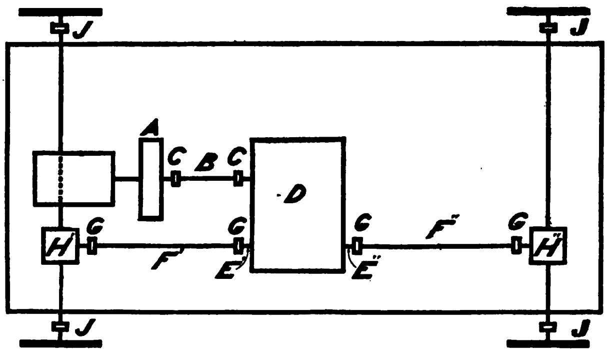


Fig. 243

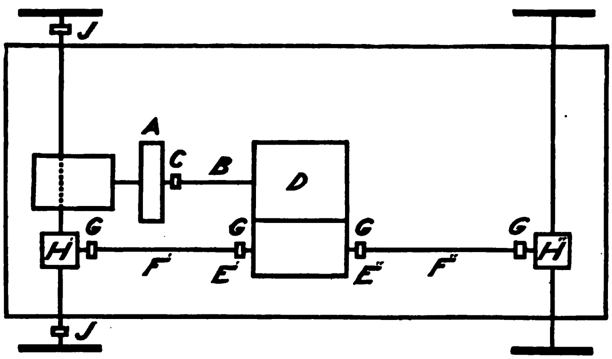


Fig. 244

When the truck is arranged to drive and steer with all four wheels it requires a different arrangement of the power transmission units. The power must be transmitted not only to the rear wheel but also to the front wheels. The general arrangement of the parts is shown in Fig. 243. In this arrangement the power is transmitted from the engine to the transmission D through the clutch A and shaft B with universal joints C. The transmission instead of having one shaft projecting to connect to the drive shaft is so arranged that there is a shaft E having both ends E' and E'' projecting and offset slightly from the centre line of the truck. From the transmission the power is transmitted to the differentials H' and H'' by drive shafts F' and F'' employing universal joints G. From the differentials the drive is transmitted to the wheels by the axles which employ universal points at J.

When four-wheel drive is employed with two-wheel steering the arrangement of parts is shown in Fig. 244.

The power is transmitted from the engine to the transmission D through the clutch A, shaft B, and universal joints C. Here the construction differs. A differential E is driven by a chain direct from the transmission, the two forming a unit. From this centre differential two shafts E' and E'' project in opposite directions. These shafts are connected to the differentials H' and H'' on the axles by the drive shafts F' and F'' with universals G. The power is transmitted to the wheels by the axles. The front axle is equipped with universal joints J.

In the following chapters the different units making up the power transmission system will be discussed in the order in which they are generally found on trucks and motor cars. The function, operation, and different types will be treated fully.

CHAPTER XXII

CLUTCHES

Every motor vehicle propelled by a gasoline engine requires some device to disconnect the engine from the remaining part of the power transmission system. The device used to accomplish this is called "a clutch."

A clutch has one member positively driven by the engine and the other attached to the transmission shaft. When these members are separated the engine will run without driving the transmission shaft thus permitting the gears to be shifted easily. The surfaces of the clutch members should be of such material that the driven member slips on the other when pressure is first applied. As the pressure is increased the driven member is gradually brought to the speed of the other member the slippage entirely ceasing and the two making firm contact. This drive is accomplished by the friction between the two members which depends upon the materials in contact and the pressure forcing them together. This force must be sufficient to prevent slipping when the clutch is engaged and the surfaces must be of such material as to provide sufficient friction to carry the load. The clutch must be easy to operate, requiring as little exertion as possible on the part of the driver. It must not take hold too suddenly or it will cause a jerky operation of the car and put a tremendous strain on the rest of the power transmission units. Provision must be made so that the tension with which the members are held in contact may be varied. It is desirable to have the driven member as light as possible so that it will not continue to rotate for any length of time after the clutch has been disengaged. Protection from dirt and dust should be provided to protect the friction material from excessive wear. For this reason practically all clutches on modern motor-propelled vehicles are housed.

When a clutch is disengaged the driven member will continue to spin due to its inertia. The heavier the driven member the longer this spinning will continue. When shifting gears it is desirable to have the speed of the transmission shaft reduced and a clutch brake is often provided to reduce the speed of the driven member. This is accomplished by bringing this part in contact with some

stationary part of the car when the clutch pedal is fully depressed. Care must be exercised not to depress the foot pedal too far so that the clutch brake entirely stops the driven member. This would cause the transmission shaft to be at rest, making the shifting of gears difficult.

Actual constructions of clutches vary on every make of motor vehicle but they may all be grouped under three general headings; cone clutches (internal and external), multiple disc clutches (wet and dry), and plate clutches (wet and dry).

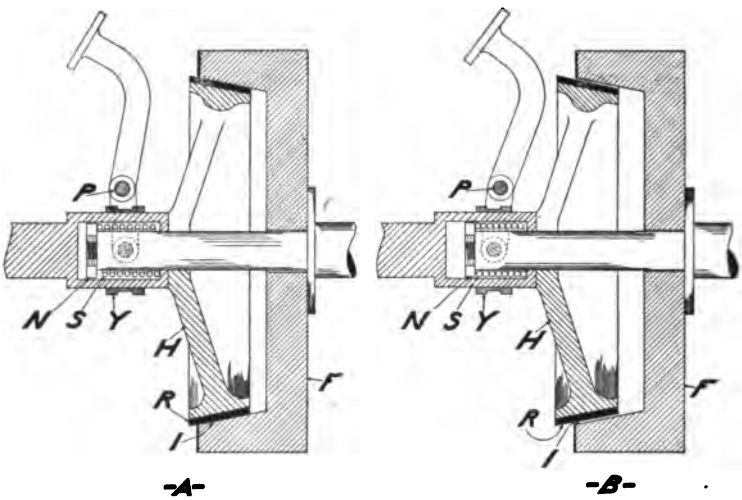


Fig. 245 — External cone clutch

Figure 245 shows diagrammatically an external cone clutch in two positions. *A* shows the clutch engaged and *B* shows it disengaged. The driving member of the clutch is the flywheel *F*, the inner surface *I* of which is conically machined at an angle 12° to 15°. The driven member of the clutch is the housing *H* which is lightly constructed and is supported by a bearing on an extension of the crank shaft. It is conically shaped to fit perfectly with the inner surface of the flywheel. The conical surface is faced with some high frictional material *R* such as leather or Raybestos. These surfaces *I* and *R* are forced together by the action of the spring *S*. This spring tension can be adjusted by nut *N*.

To disengage the clutch a foot pedal operated by the driver is provided. It is pivoted at *P* and the lower end is forked engaging a yoke *Y* attached to the housing *H*. When the pedal is pushed forward it moves part *H* backward so that the surfaces *I* and *R* are no longer in contact. This permits the flywheel to revolve inde-

pendently of part H; thus the engine is disconnected from the power transmission system. To disengage the clutch it is necessary to compress the spring S which requires considerable pressure on the yoke Y. Hence the pedal is constructed with sufficient leverage to require little effort on the part of the driver.

To function properly the clutch should be released gradually. This permits slipping between the surfaces I and R resulting in a gradual application of power to H until the spring S exerts its full pressure. This forces the two friction surfaces together so that they turn as one.

Figure 246 shows the cone clutch used on the Buick four-cylinder automobile. The springs holding the clutch in engagement are arranged differently from that shown in Fig. 245 but the operation is identical. The expander springs are provided to press the leather facing out at several points and assure gradual engagement of the clutch. This practise is quite common where leather-faced cone clutches are used.

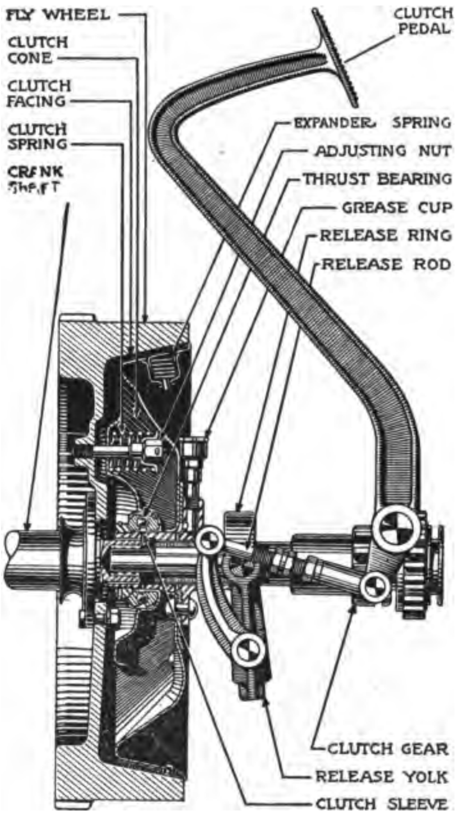


Fig. 246 — Typical cone clutch

Figure 247 shows diagrammatically an internal cone clutch in two positions. A shows the clutch engaged and B shows it disengaged. The operation of this clutch is identical with that of the external type. It is held in engagement by the spring S and is disengaged by depressing the foot pedal. It differs in that the spring S is placed inside the driven member H. The spring forces H to the rear to engage the friction surfaces R and I. Adjusting nut N regulates the tension on the spring as before.

This type was originally designed to protect the friction surfaces better from exposure to dust and dirt of the road. The general

adoption of clutch housings has eliminated this design because of the difficulty in disassembling it.

Cone clutches are usually faced with leather. To secure smooth action the leather must be kept soft and pliable by the frequent application of neat's-foot oil. If this is neglected the leather becomes hard and dry resulting in "grabbing" even when the foot pedal is gradually released. This puts sudden strains on the power transmission units causing the car to operate jerkily.

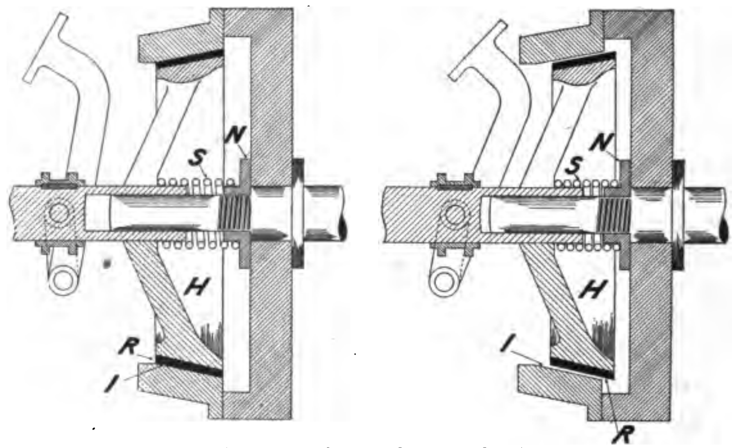


Fig. 247 — Internal cone clutch

If oil or grease is allowed to accumulate on the surface of a leather-faced cone clutch slipping will result when the clutch is engaged. This can be temporarily overcome by applying Fuller's earth but the leather should be thoroughly washed with gasoline and then treated with neat's-foot oil at the earliest opportunity.

Figure 248 shows diagrammatically a multiple disc clutch. Its principle of operation is the same as that of the cone clutch. The power from the engine is transmitted to the driven member by friction. The friction surfaces are held in contact by a spring *S* which is released by depressing a foot pedal. The tension on this spring is adjustable by means of the nut *N*. Shaft *F* from the engine has plates or discs *R* keyed to it. Between these plates are placed plates or discs *I* keyed to the housing *H* which is attached to shaft *T* running to the transmission. Both sets of plates *R* and *I* are free to move laterally but must revolve with the members to which they are keyed. When the foot pedal is released the spring *S* forces these plates together and the friction between them causes the assembly to revolve as a unit. As the clutch engages there will be a slippage between the plates until the spring tension has forced

all the plates tightly in contact. When disengaging the clutch the spring is compressed and the housing H is moved to the rear. This, however, does not separate the plates I and R. Cork or spring inserts are often placed in one set of plates to accomplish this and prevent " dragging." In some clutches both sets of plates are of

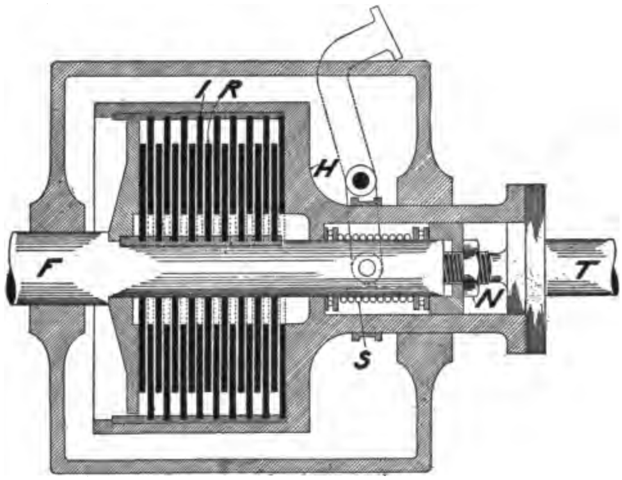


Fig. 248 — Multiple disc clutch

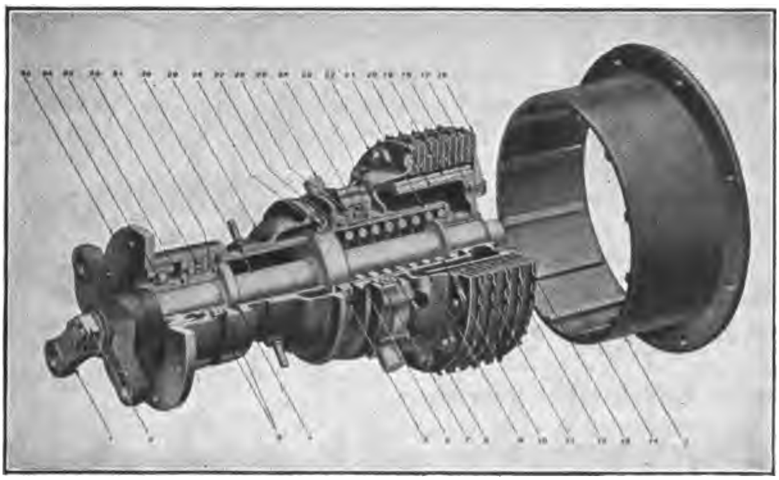


Fig. 249 — Packard clutch

metal, one set usually being made of bronze and the other of steel. This construction is usually found where the plates run in oil. Multiple disc clutches that run dry generally have one set of plates covered with some high friction material such as Raybestos.

Figure 249 shows the multiple disc clutch used on the Packard trucks. It is a dry clutch composed of two sets of steel discs. The set which is keyed to the housing bolted to the flywheel is faced with special friction material.

Figure 250 shows the multiple disc clutch used on the F. W. D. trucks. This is the Helé Shaw clutch and the discs run in oil. There are two sets of discs, one of steel which is keyed to the transmission shaft and one of bronze which is keyed to the housing bolted to the flywheel. These discs are V-grooved (Fig. 251) which increases the amount of friction surface. To separate the plates when the clutch is disengaged, disengaging springs are used. The operation of this clutch is identical with all other multiple disc clutches.

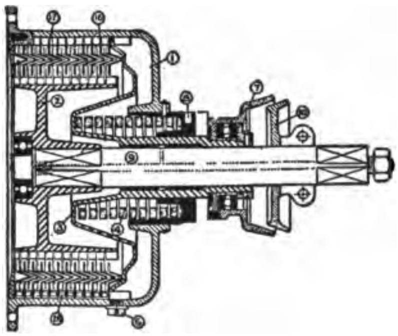


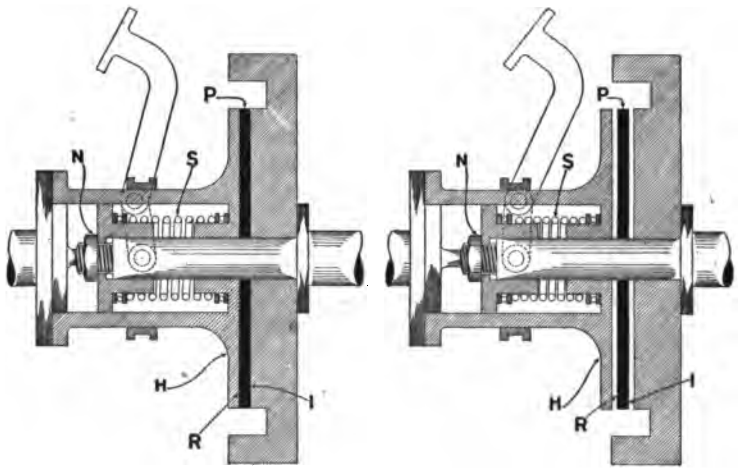
Fig. 250 — Helé Shaw clutch

Figure 252 shows diagrammatically a plate clutch in two positions. *A* shows the clutch engaged and *B* shows it disengaged. The principle of operation of this clutch is the same as that of the cone clutch. The power of the engine is transmitted to the driven member by friction. The friction surfaces are held in contact by spring *S* which is released by depressing the foot pedal. The tension on the spring *S* may be adjusted by means of the nut *N*. Between the housing *H* and the machined face of the flywheel *I* is placed a plate *P* of special friction material independent of all moving parts. When the clutch is gradually engaged slippage takes place between the surface *R* and plate *P* and surface *I* and plate *P*. This permits a more gradual application of power than if the friction material were fastened to either the flywheel or housing. As the pressure of the spring increases forcing the plate *P* and surfaces *I* and *R* together the slippage ceases and the whole assembly turns as one unit.

Fig. 251 — Discs in Helé Shaw clutch

Plate clutches are sometimes constructed with two plates of friction material separated by a steel disc pinned to the flywheel. The increased surfaces permit more slippage and therefore give a smoother operating clutch. Plate clutches are built to run dry or in a bath of oil depending upon the materials used.

Figure 253 shows the dry plate clutch used on the Nash trucks. The spring *14* forces the friction surfaces *5* in contact with the flywheel. The power of the engine is transmitted from the flywheel



A *B*

Fig. 252 — Plate clutch

to the drive plate *2* which is keyed to shaft *16* connected to the transmission.

The White plate clutch runs in a bath of light oil (Fig. 254). The operation of this clutch is as follows: The spring *15* forces housing *14* forward and in so doing raises arm *10* to which are attached the wedge-shaped pieces *11*. As part *16* is stationary the wedge-shaped part will force the friction surfaces together thus permitting the flywheel to drive the friction plate *3* which is bolted to the clutch shaft *7* connecting with the transmission.

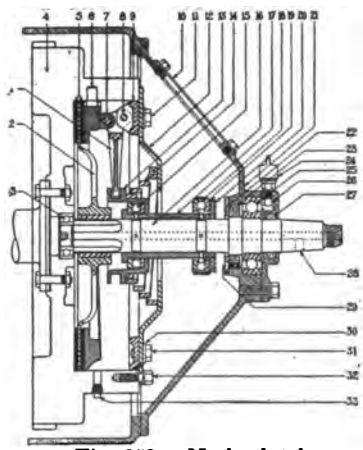


Fig. 253 — Nash clutch

When the foot pedal is depressed the wedge-shaped part *11* is lowered thus permitting the friction surfaces to separate and the flywheel to turn without driving the friction plate *3*.

There are three general clutch troubles; slipping, gripping, and dragging.

Slipping as previously explained may result from the condition

of the friction surfaces. Dry clutches slip when too much oil has accumulated on their surfaces. Wet clutches sometimes slip when too heavy a lubricant is used as the spring tension will not be sufficient to force the oil from between the plates. This prevents the friction surfaces from coming intimately into contact. It is particularly true of multiple disc clutches. Slipping is usually the result of insufficient spring tension since the friction between the surfaces depends upon the pressure exerted by the spring. This is remedied by tightening up on the clutch adjusting nut.

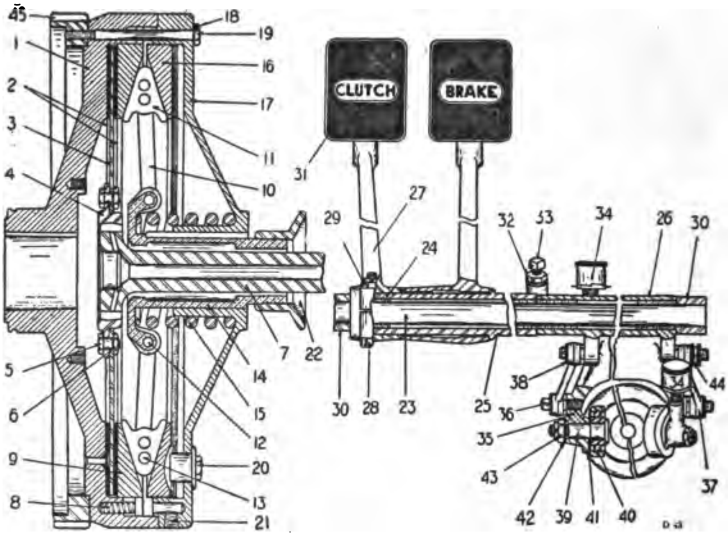


Fig. 254 — White clutch

Gripping may be the result of the condition of the friction surfaces as has already been explained under cone clutches. However, it is usually the result of too much spring tension due to the adjusting nut being too tight. This nut should be loosened until the proper spring tension is obtained.

Dragging results from the adjusting nut being so tight that considerable spring tension is exerted even when the clutch pedal is released. In a wet clutch, if the oil is too heavy or is left in the clutch so long that it becomes "gummy," the plates will adhere and dragging will result. This is particularly true of multiple disc clutches. It is remedied by washing out the clutch with kerosene and refilling with proper lubricant.

CHAPTER XXIII

TRANSMISSIONS

An internal combustion engine does not develop its full power at low speeds, therefore, an automobile engine cannot pull much of a load at low speed and gears must be interposed between the engine and driving wheels. This permits the crank shaft to turn at the speed necessary to produce the desired power while the wheels turn at the speed the road conditions or grades require. To secure flexibility of operation three and sometimes four speed ratios are provided. To back the car a set of gears are arranged in the transmission to reverse the direction of the drive transmitted to the wheels. The gears, shafts, and other parts necessary for varying the forward speed and obtaining a reverse are all contained in a housing or gear case and the assembly is called a transmission although it would be more correct to call it a gear set.

The transmission may be located in any one of three places; as part of a unit with the engine and clutch, as a separate unit between the clutch and rear axle, or as part of a unit with the rear axle which is very rarely found on modern motor vehicles.

Before taking up transmissions proper, gears will be briefly discussed. By the use of gears a mechanical advantage is obtained permitting heavy loads to be lifted with the minimum amount of power.

At A (Fig. 255) a weight W is shown supported by a rope wound about a roller R. When the crank C is turned the rope is wound

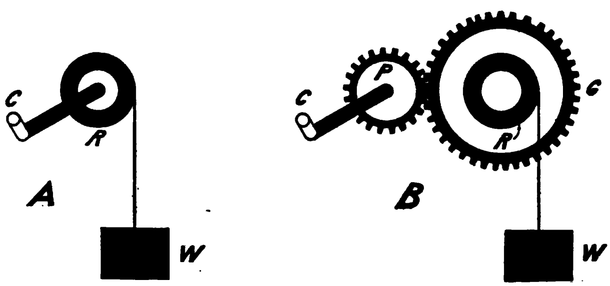


Fig. 225 — Mechanical advantage of gears

upon the roller lifting the weight. The amount of force required to lift the weight will depend upon the length of the crank arm C

and the diameter of the roller *R*. At *B* (Fig. 255) is shown the same weight supported by the rope wound on a roller *R* of exactly the same size but which is made fast to the large gear wheel *G*. Meshing with *G* is a smaller gear or pinion *P* to which is attached a crank *C* the same length as before. When the crank is turned pinion *P* revolves causing gear *G* to revolve also and lift the weight *W* by winding up the rope on roller *R*. The force required to lift weight *W* in this case will be considerably less than before because of the gear reduction between the crank *C* and roller *R*. In both cases the total work done is the same which is lifting the weight through a certain distance. In the first case one revolution of the crank winds one turn of rope upon the roller lifting the weight a corresponding amount. In the second case one revolution of the crank does not turn the gear *G* one revolution because the pinion *P* can turn *G* only as many teeth as are on the total circumference of *P*. If the gear had twice as many teeth as the pinion two turns of the crank would be required to revolve the roller once. Hence, two turns of the crank at *B* would lift the weight *W* only as far as one turn did at *A*, but only half as much force (disregarding friction) would be required. It can thus be seen that the force necessary to do a given amount of work can be reduced by the use of gears. The reduction depends upon the number of teeth on the two gears in mesh.

By the use of gears in the transmission an automobile engine is able to pull a heavy load up a steep grade. Their use also explains why the speed of the machine decreases while the engine continues to run as fast or even faster than before.

When two gears are meshed, one driving the other, they will rotate as shown in Fig. 256. At *A* is shown two spur gears in mesh.

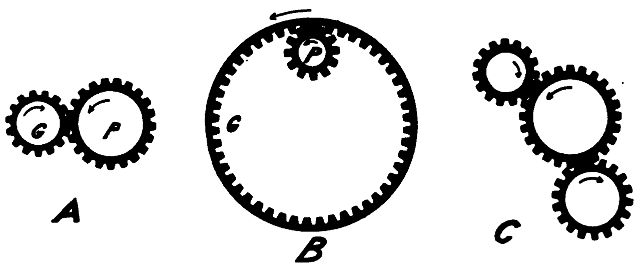


Fig. 256 — Rotation of gears

If *P* turns as indicated it will drive *G* in the opposite direction. At *B* is shown an internal gear and pinion in mesh. If *P* turns as indicated it will drive *G* in the same direction. The rotation of

combinations of more than two gears such as shown at C can be traced out the same fundamentals applying.

The expression "gear ratio" or "gear reduction" means the relation between the number of teeth on one gear as compared to the number on the gear which is driven by it. For example, if one gear has 12 teeth and drives a gear having 42 teeth the gear ratio is 42 to 12 or $3\frac{1}{2}$ to 1. This term will be used throughout the following chapters on the power transmission system wherever gears are encountered, hence, must be clearly understood.

The earliest form of transmission was a friction type in which no gears were used. This gave unlimited speed ratios between the engine and drive shaft and also eliminated the clutch.

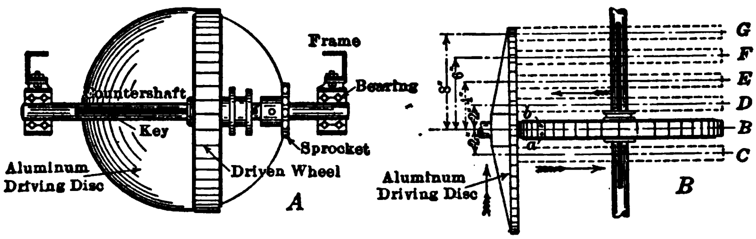


Fig. 257 — Friction transmission

Figure 257 shows two views of a friction transmission. The driven wheel slides on a counter-shaft and can be shifted across the face of the driving disc and engaged at different positions at varying distances from its center. The further the driven wheel is moved toward the outer edge of the disc the greater will be its speed. For example, the greatest speed will be obtained when the wheel is in position G and the least at position D. To obtain reverse the wheel is simply shifted to the other side of the disc to some position such as C.

The drive is interrupted by moving the driving disc forward. Friction is obtained between the driving disc and driven wheel, usually faced with fibre, by pressure exerted on the disc by a spring (not shown). In this way clutch action is obtained.

Since only a very small amount of contact surface is possible with this transmission slipping results when heavy loads are pulled. This wears out the friction surface rapidly. A much heavier spring than that used for ordinary clutches is required since the contact surfaces are smaller. The disc and wheel must be made so large for heavy pulling that the construction becomes cumbersome making its use prohibitive on all but the lightest machines.

To obtain positive transmission of power gear types of transmissions were developed. There are three types now in common use. These are the progressive, the selective, and the planetary. The different gear ratios are obtained by bringing different combinations of gears into action. In the selective and progressive types this is accomplished by shifting gears or dogs.

The progressive type of transmission has but one set of sliding gears shifted by moving a lever forward one notch for each higher ratio. From the neutral position the lever is moved straight backward for reverse. A typical three-speed progressive gear set is shown in Fig. 258, the positions of the gears when in neutral, low, second, high, and reverse being shown.

The power of the engine is transmitted to a short hollow shaft *A* called a sleeve which carries a gear *B* that is in permanent mesh with a gear *C* on the end of the countershaft. Parallel to the countershaft is another shaft, one end of which is supported by a bearing in the hollow sleeve. Though the sleeve supports this shaft the two may revolve independently of each other. The second shaft is square or of such construction that the two paired gears may slide along but must revolve with it. The gears on the square shaft are of different sizes and in sliding come successively into mesh with gears carried on the countershaft. Because the gears *B* and *C* are in mesh the countershaft revolves when the engine revolves, but the speed of the square shaft depends on the combination of gears in mesh between it and the countershaft. When the sliding gears are in such a position that they are not in mesh with the countershaft gears the square shaft is independent of the countershaft and may revolve or be stationary. The gears are then in the **neutral position.** When the sliding pair is moved so that its larger gear is in mesh with the smallest of the countershaft gears *G*, the square shaft will revolve at a slower speed than the countershaft because its gear is larger than the one driving it. This is **low speed position.** Again sliding the moving pair will separate these gears and bring the next pair *E* into mesh the square shaft then moving at a higher speed. It still moves slower than the countershaft because of the difference in the size of the gears. Sliding the moving pair still farther along the shaft will disengage the **second speed gears** and engage the high speed in which the square shaft revolves at the speed of the sleeve and crank shaft. This is effected by locking the moving pair to the sleeve by means of a dog *G*. This dog consists of several fingers projecting from the moving pair corresponding to the spaces between similar fingers on the end of the sleeve. The locking together of the square shaft and sleeve gives

direct drive. In direct drive the power of the engine is directly applied to the square shaft avoiding the loss that occurs through the friction of the gear teeth at other speeds. The revolution of the square shaft is transmitted to the driving wheels, the speed of the car corresponding to the speed at which the square shaft is driven

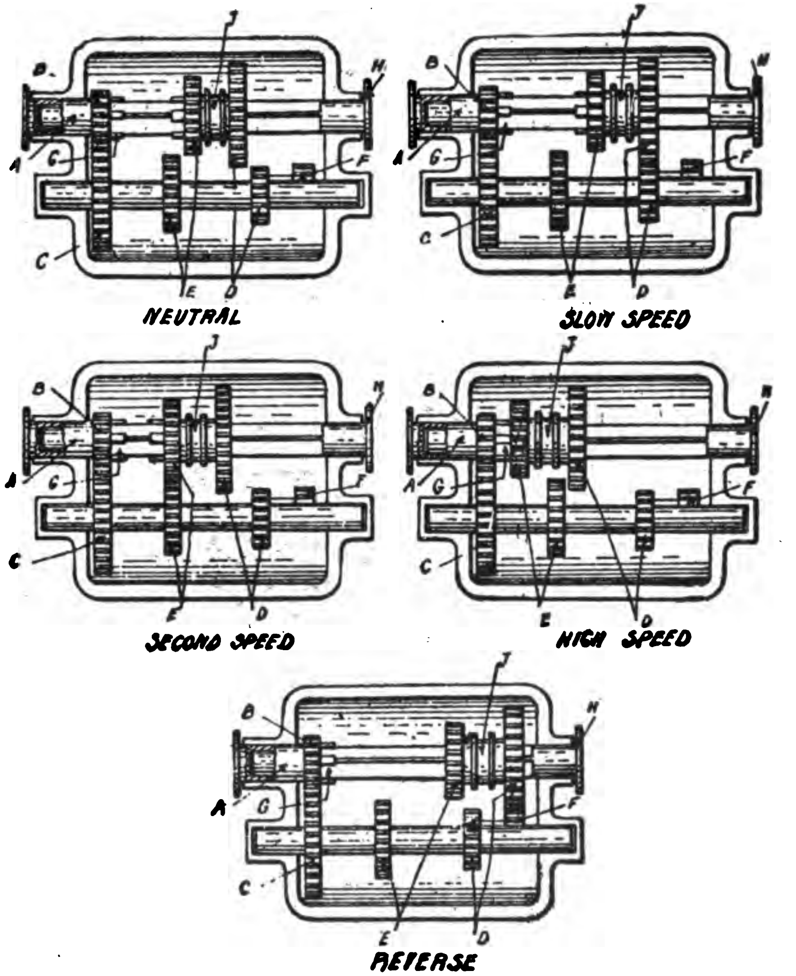


Fig. 258 — Progressive transmission

by the gear combinations between it and the countershaft.

To obtain the **reverse** which enables the car to be backed without reversing the engine, a third gear *F* is introduced between the low speed gears of the square shaft and countershaft. When the car is going forward the square shaft and countershaft revolve in opposite

directions. When the reverse gear is introduced between them the square shaft is revolved in the same direction as the countershaft reversing the rotation of the driving wheels.

This type of transmission will rarely be found on modern motor vehicles, the principal objection being that it is necessary to pass through one or more gears in shifting from high back to neutral. If this shift is made when the car is in motion stripped gears may result.

A modified form of this type sometimes called a semi-progressive transmission is used on motor-cycles. Figure 259 shows the three-

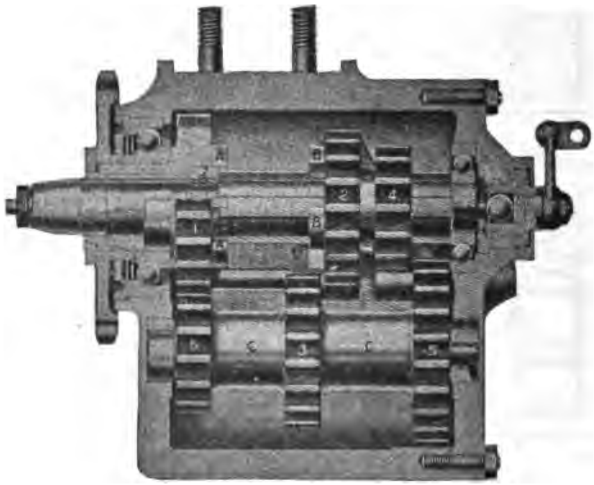


Fig. 259 — Indian motor cycle transmission

speed gear set used on the Indian motor-cycle The gears are shown in the neutral position which is between the low and intermediate gears on the countershaft. Motor-cycles not requiring a reverse gear, intermediate is the only gear that must be passed through in going into high or back to neutral. This modified type of progressive gear set will generally be found on modern motor-cycles.

The selective type of sliding gear transmission is so called because it is possible to engage any set of gears desired in moving from the neutral position without passing through any other gears. Selective gear sets are constructed with either three or four speeds forward and a reverse.

Figure 260 shows a typical three-speed gear set in which the position of the gears when in neutral, low, intermediate, high, and reverse is shown.

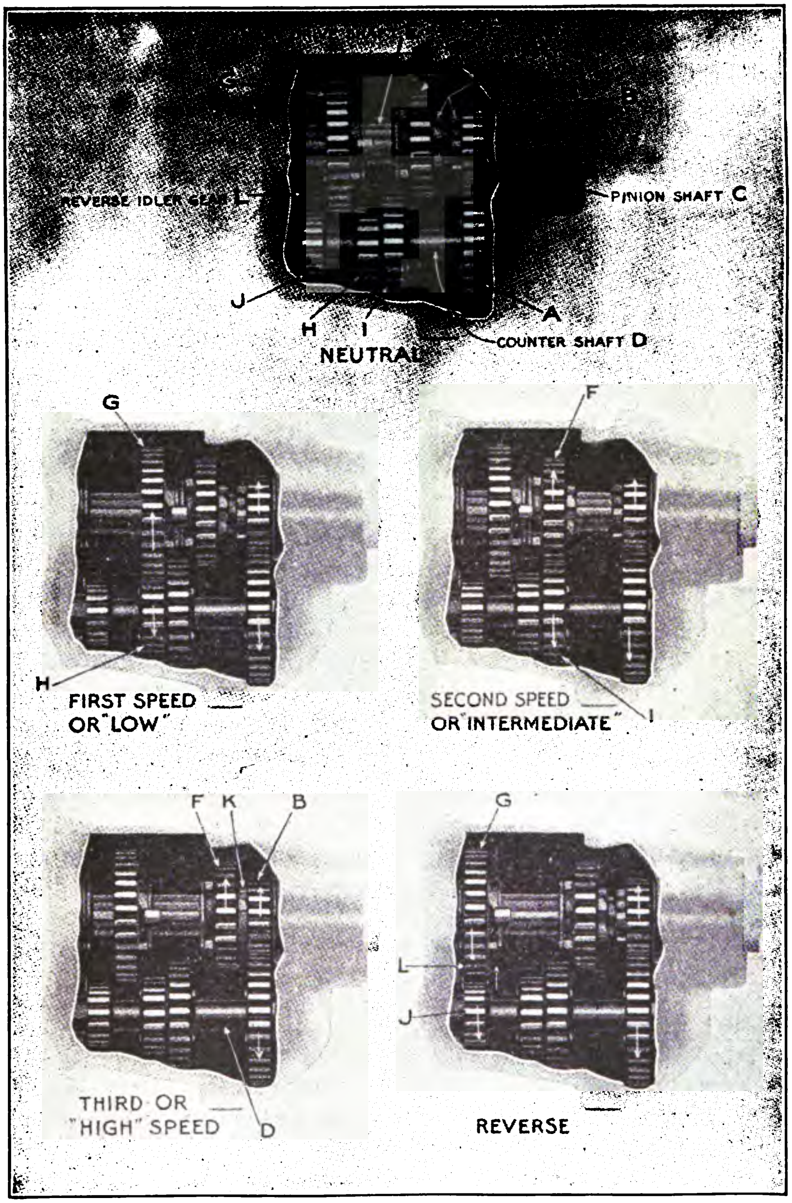


Fig. 260 — Selective transmission

The revolution of the engine is transmitted to the countershaft *D* through the gears *B* and *A* which are always in mesh. All gears on the countershaft are permanently keyed to it. The shaft *E* is supported at one end by a bearing in the hollow end of the shaft coming from the engine and at the other end by the bearing where it passes through the transmission case for attachment to the drive shaft. The gears *F* and *G* are free to slide along shaft *E* but are forced to turn with it because of the keys on its surface. Each of these sliding gears have collars forged on them in which shifter forks engage as shown in Fig. 261.

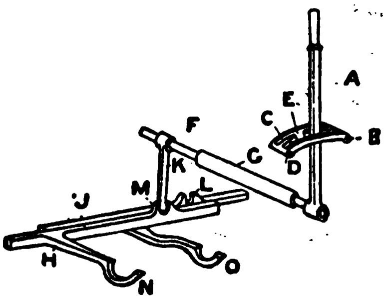


Fig. 261 — Gear shift mechanism

The movement of the gear shift lever *A* to the right or left picks up one or the other of these forks shifting the particular gear to which it is attached. When the gear shift lever is in neutral position the gears will be shown in **neutral** (Fig. 260). If the gear shift lever is moved to the position of **first speed** gear *G* will be moved along the shaft *E* until it meshes with gear *H* on the countershaft. If the gear shift lever is now moved in the opposite direction gear *G* will be moved to the **reverse** position. In changing from low to reverse, gear *G* passes through the same position it occupied on the shaft *E* when in neutral. If second speed is desired the gear shift lever must be moved to the opposite side of the control sector (Fig. 261) and in the opposite direction to that in going into first speed. This now causes the gear *F* to be shifted and it is moved to the position shown for **second speed.** If direct drive is desired the gear shift lever must be moved in the opposite direction shifting gear *F* to the position shown for **high speed.** In going from second to high the gear *F* passes through the same position it occupies on the shaft *E* when in neutral.

Figure 262 shows a typical three-speed selective sliding gear transmission which is is used on the Dodge car. The exact location of the reverse idler pinion is clearly shown as is also the bearing of the sliding gear shaft in the hollow end of the clutch shaft. One feature of this transmission is that the countershaft does not revolve when running on high gear. This is because the gear on the clutch shaft is shifted so that it does not drive the countershaft when in high.

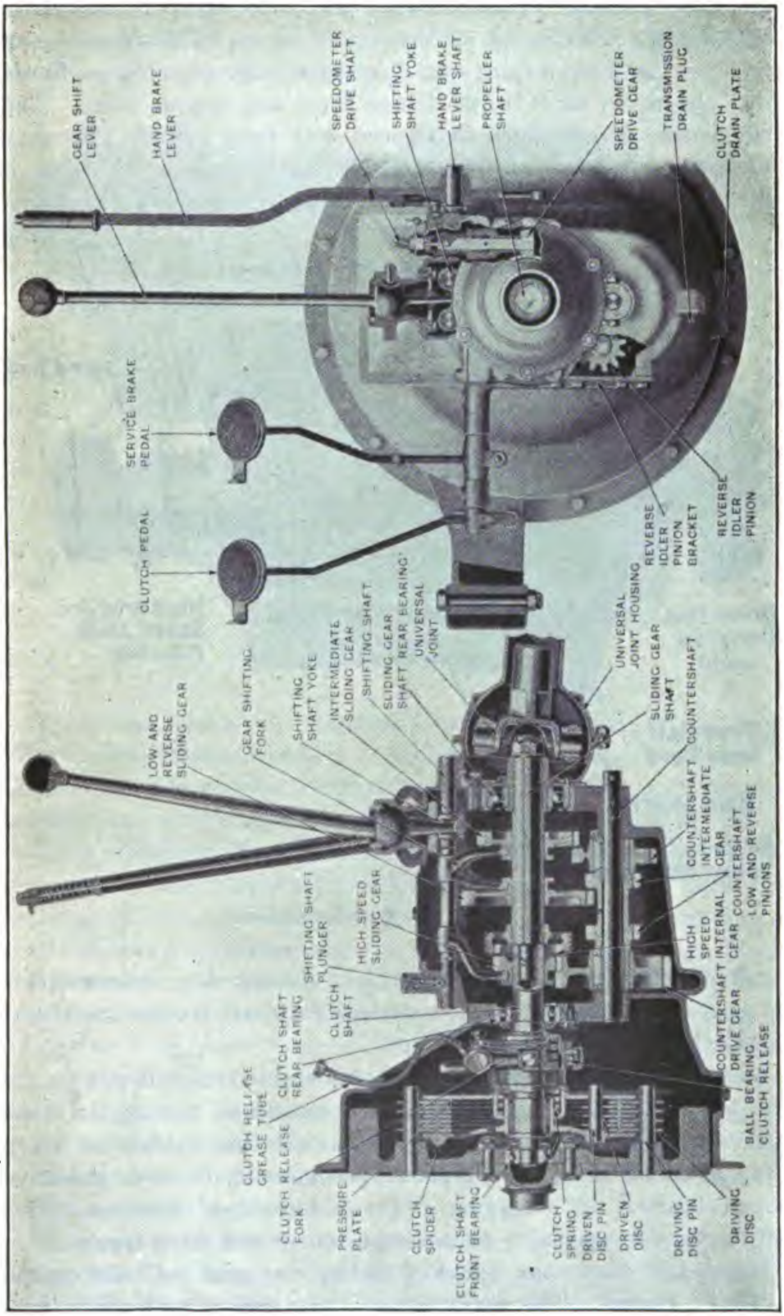


Fig. 262 — Dodge transmission

Figure 263 shows the four-speed transmission used on the White motor cars. It is identical with the three-speed transmission except for the addition of another set of gears. This transmission is arranged so that on third speed the drive is direct, while on fourth speed the drive shaft turns faster than the engine shaft. This arrangement permits increased speed with light loads. The usual four-speed construction especially for trucks has direct drive on fourth speed and three lower gear ratios permitting greater flexibility

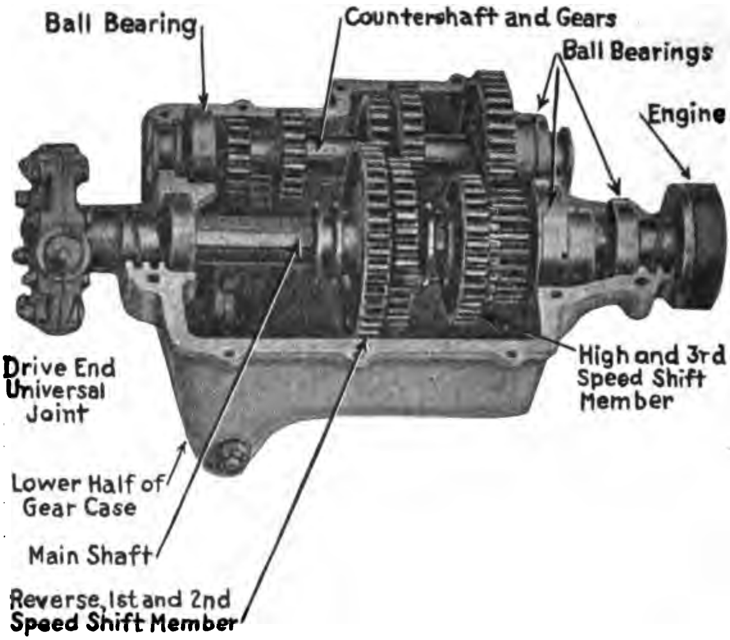


Fig. 263 — White transmission

of drive. Selective sliding gear or sliding dog transmissions are almost universally used on modern cars and trucks, the three-speed type being the most common.

When heavy loads are pulled a considerable strain is put on the gear teeth when they are being shifted sometimes causing the teeth to be stripped from the gear. To eliminate this trouble on heavy cars and trucks the gears are placed permanently in mesh, the drive being obtained by engaging dogs or individual clutches. This construction is especially desirable on four-wheel drive trucks.

Figure 264 shows the selective sliding dog gear set used on the F. W. D. trucks. The gears on the countershaft and main shaft are always in mesh. Shifting dogs are moved along the main shaft

just as the gears are shifted in ordinary selective types of transmission. One feature of this transmission is that when the high speed dog is shifted forward engaging the engine shaft a yoke throws out the dog on the countershaft so that it does not revolve.

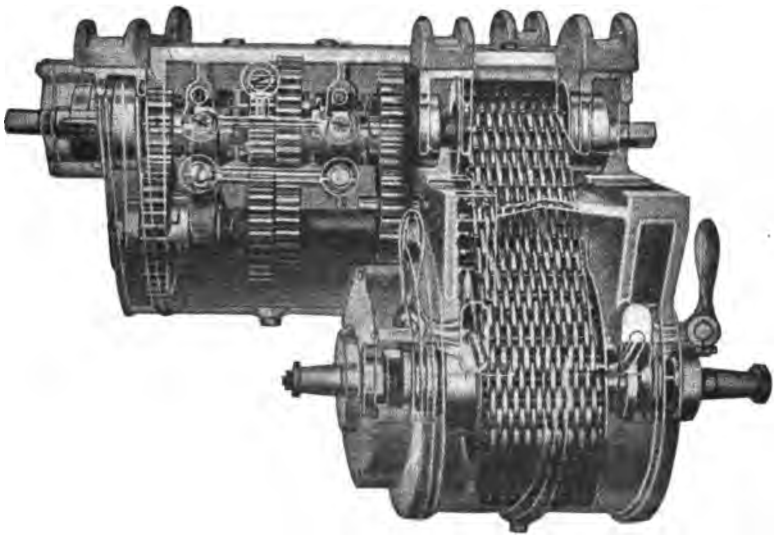
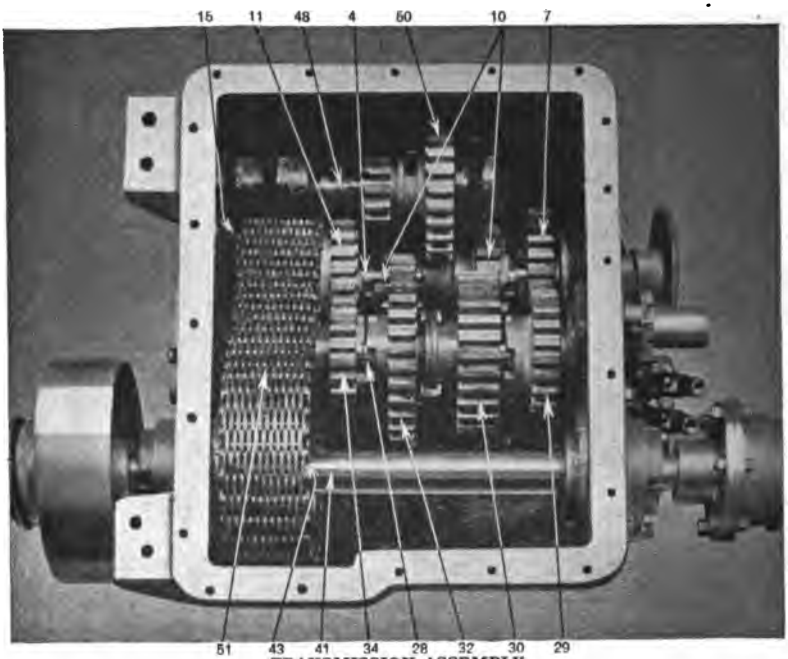


Fig. 264 — F. W. D. transmission

Figure 265 shows the selective transmission used on the Nash trucks. This transmission is of the sliding dog type but differs in having dogs and gears integral with each other. The shifting gears are provided with clutches or dogs of four jaws and are shifted on both the countershaft and main shaft. The power from the engine is applied to the main shaft *4* called the "spline shaft." Upon this spline shaft and driven by it are the sliding gears *10* consisting of a unit of two gears whose outer ends are provided with dogs. Gear *7* is free to turn on the spline shaft and gear *11* is also free to turn on it but is bolted to the drive sprocket *15*. The countershaft *28* called the "lay shaft" carries the sliding gears *30* and *32* which are provided with dogs and free to turn on it. Gear *29* is keyed to the lay shaft and in constant mesh with gear *7*, and gear *34* is also keyed to the lay shaft and in constant mesh with gear *11*. The reverse gear shaft *48* carries the reverse gears *50* which may be shifted to engage gears *10* and *11*.

When the gear shift lever is moved to **first speed** position gear *32* is shifted so its dogs engage those of gear *34*. The power is now transmitted from the spline shaft by gear *10* to gear *32*, to gear *34*, to gear *11*, and sprocket *15*, through chain *51* to the transmission



TRANSMISSION ASSEMBLY

4—Splineshaft
7—Transmission third-speed drive gear
10—Transmission splineshaft sliding gear
11—Transmission drive sprocket gear
15—Splineshaft drive sprocket
28—Transmission layshaft
29—Transmission layshaft third-speed gear
30—Transmission layshaft second-speed gear
32—Transmission layshaft first-speed gear
34—Transmission layshaft drive gear
41—Transmission countershaft
43—Countershaft drive sprocket
48—Reverse gear shaft
50—Reverse gear
51—Silent drive chain

Fig. 265 — Nash transmission

countershaft *41*. When the gear shift lever is moved to the **second speed** position the dogs of gears *32* and *28* are disengaged and those of *30* and *29* are engaged. This is accomplished because one shifting fork controls both gears. The power is now transmitted from the spline shaft by gear *10* to gear *30*, to gear *29* and shaft *28*, to gear *34*, to gear *11*, and to the countershaft as before. In moving the gear shift lever from second to **third speed** position the neutral position is passed through which disengages gear *30*. Gear *10* is moved forward its dogs engaging those of gear *7*. The power is now transmitted from the spline shaft to gear *10*, to gear *7*, to gear *29* and shaft *28*, to gear *34*, to gear *11*, and to the transmission countershaft as before. When the gear shift lever is in **fourth speed** position the dogs of gear *10* are disengaged from those of gear *7* and engaged with those of gear *11*. The power is now transmitted directly from the spline shaft by the dogs of gear *10*, to gear *11*, and to the transmission countershaft as before. When

the gear shift lever is in **reverse** position, gear *50* meshes with gear *10* and the pinion paired with gear *50* meshes with gear *11*. The power is now transmitted from the spline shaft through gear *10*, to gear pair *50*, to gear *11*, and to the transmission countershaft as before, rotation being in the opposite direction.

The planetary transmission differs from the progressive and selective types in that the groups of gears always remain in mesh and revolve around a main axis. The different sets of gears are brought into action by stopping the revolution of the parts which support the gears. To hold these parts from revolving brake bands are commonly used. In this way a simple operating transmission can be constructed having no dogs or gears to be meshed when changing speeds.

To understand the operation of the Ford planetary transmission it is necessary to know fully the exact assembly of the parts. In Fig. 266 the transmission parts are shown in their relative assembling positions and the groups in their different stages of assembling.

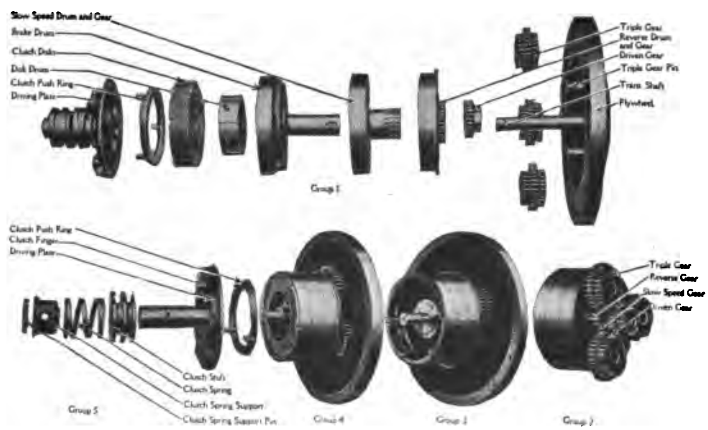


Fig. 266 — Ford transmission disassembled

The first operation is the assembling of group 2 which is as follows: Place the brake drum on the table with the hub in a vertical position. Then place the slow-speed drum and gear over the hub with gear uppermost. Next place the reverse drum over the slow speed drum so that the reverse gear is just behind the slow speed gear. Then place the driven gear in position so that the teeth will be downward and key it to the brake drum housing. The triple gear should now be meshed with the gears attached to each of the drums so that the punch marks line up. The gears should then be tied so that they cannot move.

The assembly should now be placed on the flywheel as shown in group 3 so that the triple gears fit on the triple gear pin and the transmission shaft extends beyond the inner face of the brake drum. The clutch drum key should be fitted in the transmission shaft so that it will hold the clutch drum rigid to it when put in place. The clutch drum should next be placed on the transmission shaft and the set screw fastened. The clutch plates should next be placed over the clutch drum. Put a large disc on first then a small disc alternating with large and small discs until the entire set is assembled in position. The large discs are keyed to the brake drum and

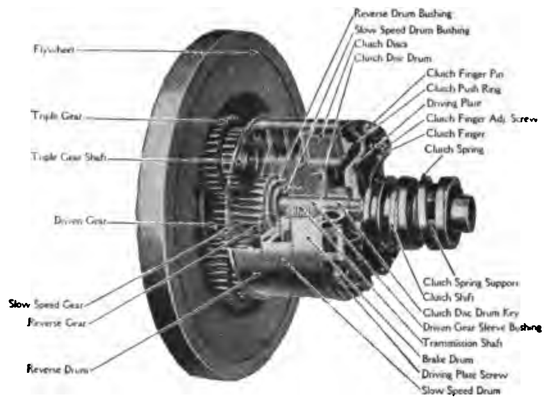


Fig. 267 — Assembled transmission

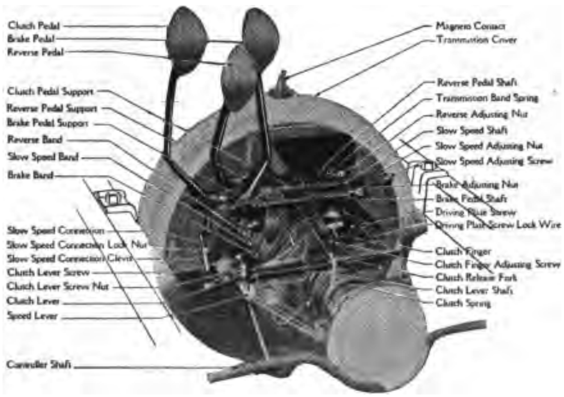
the small discs are keyed to the disc drum so that they must revolve with the parts to which they are keyed but can be moved backward or forward. Next put the clutch push ring in place and attach the driving plate to the brake drum so that the studs on the clutch push ring press against the clutch fingers. Then place the clutch shift, clutch spring, and clutch spring support in place and fasten with clutch spring and support pin. The assembly is now complete (Fig. 267). Figure 268 shows the pedals and brake bands attached in their proper places.

Figure 269 shows diagrammatically the arrangements of the parts of the Ford planetary transmission in cross-section and will be used to explain its operation.

High Speed. — When the foot clutch pedal is released it allows collar C to force arms A forward. This forces the plates of the clutch together so that the shaft S and housing B are driven as one unit. Every time the flywheel F makes one revolution the housing B also makes a complete revolution. In this manner drive is obtained, the entire transmission revolving as one unit and the

drive is taken through the clutch. At all other speeds the clutch is out of operation and the clutch pedal must be depressed slightly to free it.

Slow Speed. — When the clutch pedal is depressed all the way it



Fif. 268 — Control pedals

not only releases the clutch but causes a brake band to hold fast the drum *L*.

As the flywheel from which project the studs carrying the triple gears (Fig. 269) revolves it will be necessary for the gears to revolve

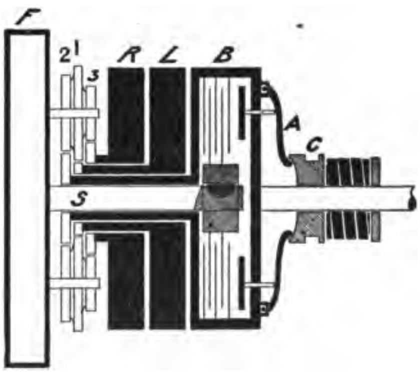


Fig. 269 — Sectional diagram of Ford transmission

on their own axes. Assuming gear " 1 " has 20 teeth and gear " 2 " has 30 teeth (Fig. 270A) the operation will be as follows: As the gear attached to *L* is held stationary by the brake band, gear " 2 " which is in mesh with it will have to roll on gear *L*. When gear " 2 " has rolled 30 teeth to position *X* it will have turned one com-

plete revolution. As gear "2" turns one complete revolution gear "1" must also turn one complete revolution. Assuming that it rolls on gear *B* it would roll 20 teeth to a position *Y*. This cannot be true for the triple gear pinion has to be at *X*, therefore, gear "1"

Fig. 270 — Explaining operation of transmission

must drag gear *B* with it the distance from *Y* to *X*. When driving in high, gear *B* turns at the same speed as the flywheel. Now it does not turn as fast thus giving low speed.

Reverse. — In this position the clutch pedal is pressed just far enough to release the clutch. The reverse foot pedal is pressed all the way down. This contracts a brake on the drum *R* (Fig. 269). As the flywheel revolves carrying with it the triple gears the following condition will result: As the gear attached to *R* is held stationary the triple gears will have to revolve on their own axes causing gear "3" to roll on gear *R* (Fig. 270B). Assuming that gear "3" has 10 teeth it will turn one revolution when it has rolled 10 teeth on *R* and will be at position *Z*. At the same time gear "1" will have to revolve one revolution. Assuming that it can roll at the same time on gear *B* it would be at position *X* when it had turned one revolution. As it cannot be there but must be at position *Z* since *B* is free to move and *R* is not, it will have to turn *B* through the distance from *Y* to *Z*. This turns *B* in the reverse direction and at a slower rate of speed than the engine.

It must be remembered that low and reverse speeds are dependent upon the brakes holding the bands fixed assuming that the housing *B* is free to move. This is not exactly true as the weight in driving the car forms a brake on *B* thus tending to hold it fixed. The brakes on the drums *R* and *L*, therefore, must be in very good condition for they must have a greater braking force than that applied by the weight of the car and friction of the working parts of the power transmission units, or else the drums will slip under the brake bands and a loss of developed power to the drive wheels will result.

CHAPTER XXIV

DRIVES

From the transmission or gear set the power must next be delivered to the differential and thence to the wheels. It is desirable to do this in the most efficient manner by reducing frictional losses to a minimum, yet the method of drive employed must have sufficient flexibility to allow for the movement of the frame up and down on the springs. The usual method is by a shaft from the transmissions direct to the differential. In some cases where the differential is not placed on the rear axle the final drive to the wheels is made by chains.

When a shaft drive is used universal joints are necessary to secure the required flexibility. Figure 271 shows a typical universal joint.

Fig. 271 — Universal joint

By being pivoted so its parts can turn about axes perpendicular to each other one member of the joint may remain rigid while the other moves through variable angles. This ability of a universal joint to adjust itself to transmit power through variable angles makes it applicable to shaft drives.

One or more universal joints must be incorporated in the drive from the transmission to the differential. This gives the necessary flexibility to compensate for the movement of the rear axle due to spring action. Universal joints are always used at points where the drive is transmitted by shafts at variable angles. Referring to

Chapter XXII the power transmission charts show universal joints used at the following points: Between the clutch and transmission to relieve any strains occasioned by twisting the frame, on drive shafts as just explained, on axles whose wheels are both driven and steered to permit the wheels to turn.

The drive shaft may be tubular which gives it greater strength and stiffness without excessive weight. It often is enclosed in an extension of the rear axle housing or it may be exposed.

Fig. 272 — Enclosed drive shaft

Figure 272 shows the enclosed drive shaft used on the Dodge car. A construction of this kind is advantageous since it protects the moving parts and at the same time takes any possible strain on the shaft other than that of driving the car.

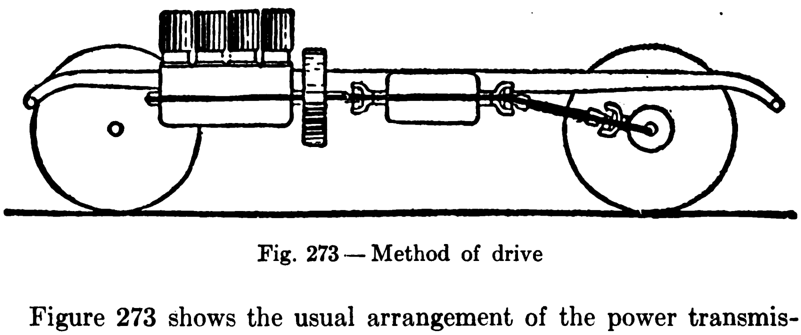


Fig. 273 — Method of drive

Figure 273 shows the usual arrangement of the power transmission units employed on shaft drive machines. There is less loss of

power due to angularity at the universal joints and less wear when the units are nearly in alignment.

In addition to universal joints a sliding or telescopic joint must be provided at some point between the transmission and rear axle because of the slight variations in the distance between them as the frame moves up and down. This joint is many times overlooked and its lubrication often neglected.

The drive shaft transmits power to the housing carrying the differential gears through a pair of bevel, helical, or worm gears. In each case the pinion (small gear) or worm is keyed to the shaft and meshes with the large driving gear or worm wheel bolted to a flange on the differential housing.

Figure 274 shows the bevel gear drive used on the Ford car. The drive shaft on which is keyed the pinion, meshes with the large drive

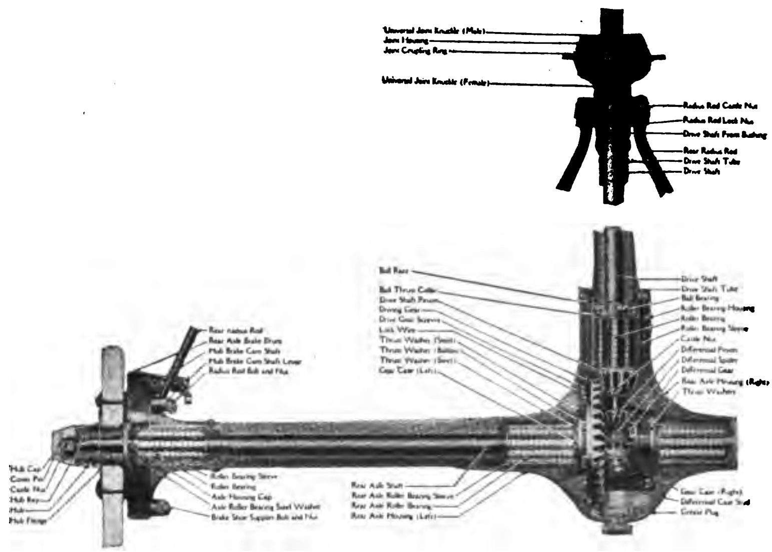


Fig. 274 — Bevel gear drive

gear (ring gear) bolted to the differential housing. When the shaft rotates the drive gear is caused to revolve, turning the axles, and in this way the drive is transmitted to the wheels. There is considerable gear reduction at the rear axle, for the large bevel gear turns one revolution to every three (or more) revolutions of the pinion. Hence, the drive shaft turns at several times the speed of the axles which correspondingly decreases the power required to drive the wheels. This is generally called "differential reduction" and will depend upon the power required.

Figure 275 shows the helical or spiral bevel driving gears. The angular cut teeth eliminate backlash and play between the teeth insuring quiet operation. In addition, continuous driving action results, at least two teeth being partly engaged at all times, overcoming any tendency to wear irregularly. This type of gear is rapidly replacing the ordinary bevel gear, with its single tooth contact.


Fig. 275 — Helical gear drive

Fig. 276 shows a typical worm drive. The worm is keyed to the drive shaft and placed above the gear wheel which is the ordinary arrangement. Several teeth are in mesh at once resulting in quiet and continuous operation. The gear wheel is usually made of steel and the worm of bronze to reduce friction to a minimum. Because of the large gear reductions obtainable with this type of drive it is particularly well suited for trucks where a differential reduction of between 7 and 9 to 1 is desired.

To obtain a large differential reduction on heavy trucks, chains are used for the final drive. Fig. 242 shows a typical arrangement of chain drive. The differential is generally housed with the transmission gears and jack shafts drive chains by means of sprockets on their ends. A dead axle is used and the wheels carry sprockets of larger diameter than those used on the jack shafts. This permits an additional reduction to that obtained at the differential. When a chain drive is used, universal joints are not necessary unless used between the clutch and transmission, since the chain is flexible and adjusts itself to the movement of the frame up and down on the springs. A chain drive is objectionable, because it is noisy and wears excessively, being exposed to the dust and dirt of the road.

A chain tends to pull the rear axle forward since all the power is

delivered by the pull of the chains on the sprockets. To keep the rear axle from being twisted out of place and also to adjust the tension on the chain, radius rods are used. These are attached by flexible couplings, usually ball joints, to the frame and axle

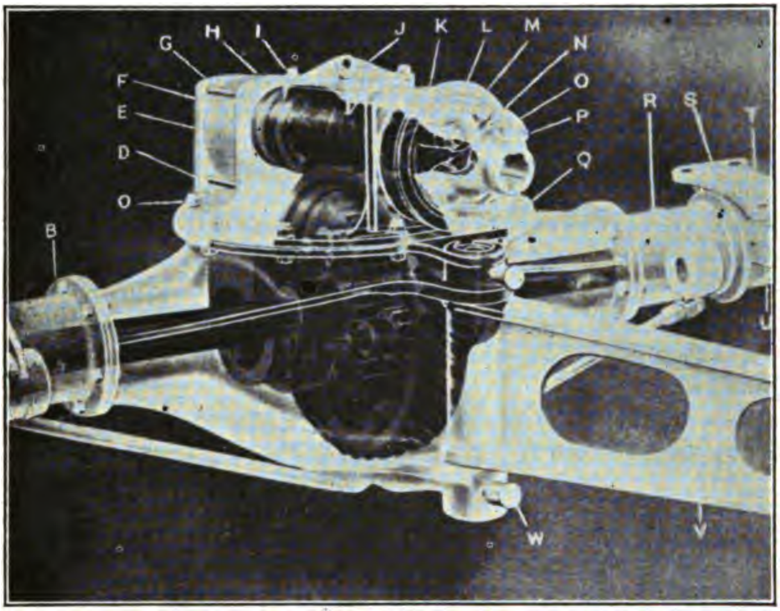


Fig. 276 — Worm gear drive

and their length is adjustable. In this way the driving strain is transmitted to the frame.

On shaft-driven machines the driving strain is transmitted to the frame through torque arms, radius rods, torque tubes, distance rods, or the springs. The torque arm is more common on heavy cars and the torque tube on lighter machines, it generally being the extension of the rear axle housing covering the drive shaft. Where the Hotchkiss drive is used (drive taken through the springs), the main spring leaf is made extra heavy to take this additional strain.

CHAPTER XXV

DIFFERENTIALS

When a car travels around a corner the distance traveled by the outside wheels is greater than that traveled by the inside wheels. If the wheels are mounted on dead axles so that they turn independently of each other, like the front wheels on an ordinary passenger vehicle, they will turn at different speeds to compensate for the difference in travel. If the wheels are positively driven by the engine, a device is necessary which will permit them to revolve at different speeds without interfering with their driving the car. To accomplish this a system of gears called " the differential " is provided.

The action of the simple differential is shown in Fig. 277. At *A* two shafts *K* and *K-1* are attached to the large bevel gear wheels

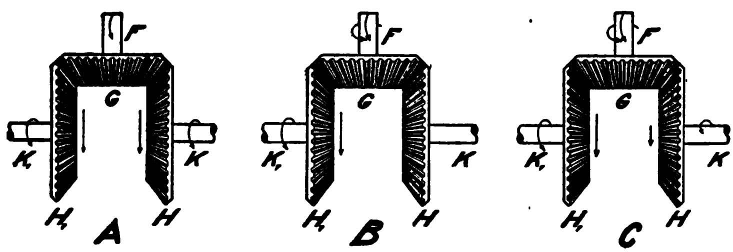


Fig. 277 — Differential action explained

H and *H-1* and meshing with them is the pinion *G* attached to the shaft *F*. When the shaft *F* is pulled forward as shown, but not rotated about its axis, the pinion *G* will not revolve. Since it is meshed with both gear wheels *H* and *H-1* they will be turned about their axes, causing the shafts *K* and *K-1* to revolve equally and in the same direction that the shaft *F* is being pulled. The pinion *G* merely acts as a connection or clutch between the two gear wheels. If the axle *K* is held stationary (Fig. 277B), its gear wheel *H* cannot revolve when the shaft *F* is pulled forward as before. This causes the pinion *G* to roll on the gear *H* revolving about its axis, while *H-1* turns at a greater speed than before. This is because it is forced to revolve at the speed with which shaft *F* is pulled forward plus the speed imparted to it by the pinion *G*

revolving on its own axis. Shaft *K-1* still revolves in the same direction that shaft *F* is being pulled. If shaft *K* is allowed to slip a little (Fig. 277C) so that it revolves in the same direction as at *A* but not nearly so much, as indicated by the arrow, the amount that pinion *G* rolls on the gear *H* will be correspondingly reduced. Shaft *K-1* will be driven as before by both the pull on *F* and the turning of the pinion *G* on its axis. Therefore, the pinion *G* will not revolve as much as it did before, since gear *H* is now also turning correspondingly, reducing the amount that the shaft *K-1* revolves.

This is the principle upon which all differentials are built, different arrangements of gears being used to accomplish this same result. In the differential, the shafts *K* and *K-1* are the axles to which the wheels are attached, either one of which may revolve slower than the driving speed. The revolution of the other increases a corresponding amount due to the differential action of the gears.

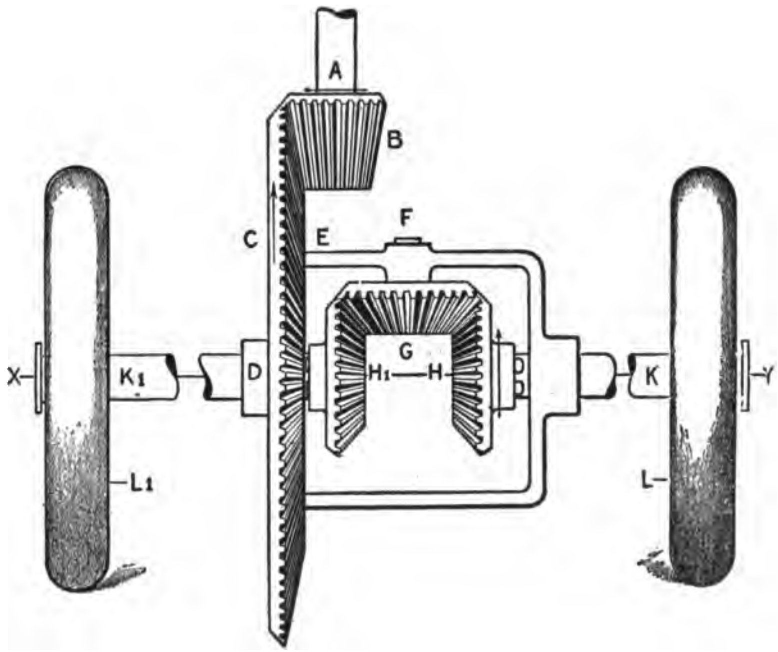


Fig. 278 — Bevel gear differential

Figure 278 shows diagrammatically a simple bevel gear differential. The pinion *G* is mounted on a short axle or stud *F* which is carried by a differential housing *E*. This housing is driven by the rear axle drive in this case, bevel gears *C* and *B* being employed. When the gear wheel *C* turns in the direction shown the differential

housing turns with it, carrying the stud F and pinion G in just the same way as when the shaft F was pulled over by hand. Any difference in the rotation of the rear wheels is compensated for by the rotation of the differential pinion G on the stud F while revolving bodily about the axis X-Y. If the pinion G rotates, it must roll on one of the differential gears H or H-1 and the amount of motion in rolling on the one gear is transmitted to the other as an additional turning or driving effort. Any retarded motion of one wheel results in an accelerated motion of the other. The rotation of the engine is thus transmitted to the rear wheels in proportion to the distance each wheel travels.

In Fig. 278 only one pinion is shown and the differential housing is merely a frame bolted to the main driving gear. In actual differentials several pinions are employed and usually the differential housing partially encloses the differential gears. There are three general types of differential gears employed on modern motor vehicles. These are the bevel gear, the spur gear, and the worm gear types of differentials.

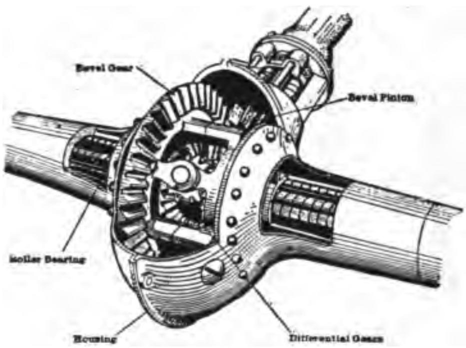


Fig. 279 — Ford differential

Figure 279 shows a typical bevel gear differential. Both the differential gears and driving gears are clearly shown. The differential housing can be seen attached to the main driving gear and carrying the differential pinions.

The objection to the bevel gear differential is, that whichever wheel offers the least resistance is turned the fastest causing a loss of traction. If one wheel gets in the mud or loose dirt or sand, the wheel on solid ground will not be driven while the other spins around due to the differential action.

The bevel gear differential was the first type developed, but the spur gear differential will be found on many modern cars. Fig. 280 shows a spur gear type of differential. The axle gears are spur

gears instead of bevel gears and the bevel pinion is replaced by two spur pinions meshing with each other at their inner ends. Their outer ends mesh with and drive the spur gears on the axles, the pinions revolving on the studs carried by the differential housing which is driven by rear axle driving gears as before. The pinions in this case revolve parallel to the axle instead of at right angles to it as in the bevel gear type.

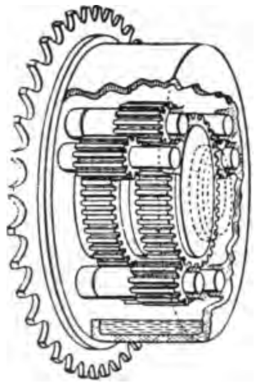


Fig. 280 — Spur gear differential

If the pinions were long enough to mesh with both the axle gears and not with each other, driving the differential housing would cause them to roll on the axle gears all rotating on their studs in the same direction, the axle gears remaining stationary. By meshing them with each other they cannot revolve in the same direction, for when two gears are in mesh they must revolve in opposite directions. This prevents the pinions from rolling around on the axle gears when the housing is revolved and as long as there is equal resistance on both the wheels they will not revolve on their studs, but will act as a lock or clutch between the two axle gears carrying them around with the housing as in the bevel gear type and having the same disadvantages.

If the machine is turning a corner the greater distance traveled by the outside wheel will cause the pinions to revolve on their studs permitting one differential gear to turn faster than the other. This is identically the same action as is obtained by the use of bevel gears.

Figure 281 shows the worm gear differential which is used on the Nash quad trucks. This differential is made with two pinions *C* mounted in the differential housing *H* which is rotated by the driving gears. The two crown wheels *A* and *A-1* are attached to the shafts driving the wheels. Between the crown wheels *A* and the pinion *C* the worm gears *B* are interposed. The worms *B* are mounted with their axles at right angles to those of the pinion *C*. When housing *H* is revolved it will carry with it the pinion *C* and worm gears *B*. If the car is traveling straight ahead these gears will not revolve on their own axes and the movement of *A* and *A-1* will be the same. Assuming that gear *A-1* was held stationary, worm gear *B* would roll on it. The worm gear *B* in turn would drive pinion *C*, but this is not possible since pinion *C* cannot drive the other worm gear *B* which is in mesh with crown wheel *A*. If the

pitch is less than 45 degrees a pinion cannot turn a worm gear but the worm can turn the pinion. This is the principle upon which this differential is constructed. As explained, if one wheel is stationary and the other free, the differential action would be locked and the free wheel would not spin. When turning a corner the action is as follows: *A-1* or *A* being driven at a greater speed than

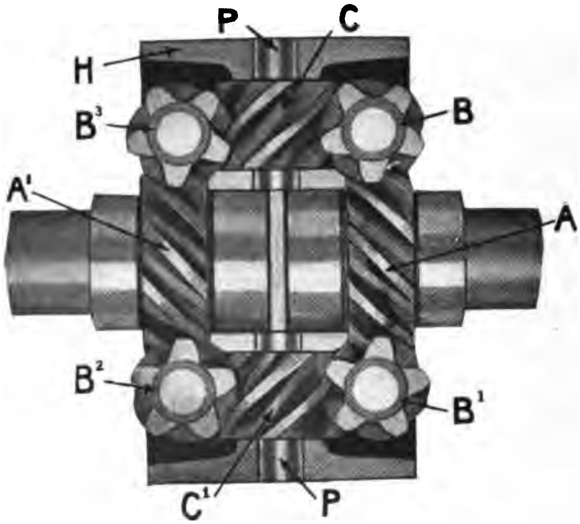


Fig. 281 — M. and S. differential

the other permits the gear *B* which is in mesh with it to roll on its surface. The one traveling faster will cause the gear *B* in mesh with it to turn on its axis, this movement being adjusted by the pinion gear *C*. From this it is seen that a differential of this construction is desirable. In case the car is ditched, the wheel which is free will not have all the turning transmitted to it thus making it possible to pull out.

When bevel or spur differentials are employed a differential locking system is often used. Figure 282 shows diagramatically the differential lock used on the F. W. D. trucks. A dog is shifted on the axle shaft so that it engages or locks with the differential housing. This prevents the differential pinions from turning and the whole system of gears turns as a unit. In this way the two drive shafts revolve equally causing both front and rear wheels to be driven.

When both the front and rear wheels are driven a differential must be placed on the front axle as well as the rear. When a four-wheel drive truck is steered by turning both the front and rear

wheels, as is done on the Nash quad trucks, both front and rear inside wheels will travel the same distance in turning a corner as will both front and rear outside wheels. This is because the rear wheels follow in the tracks of the front wheels.

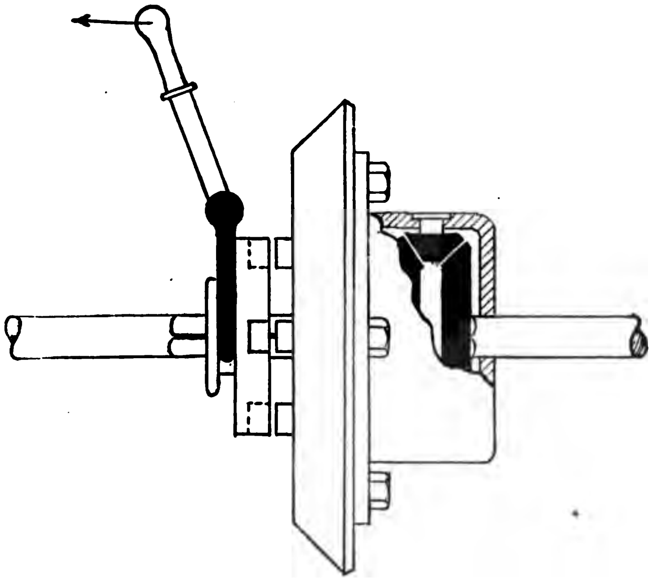


Fig. 282 — Differential lock

When only the front wheels are steered on a four-wheel drive truck such as the F. W. D. the front and rear wheels do not track when turning, the rear wheels cutting the corner. Therefore the drive shaft driving the front wheels must turn at a greater speed than that driving the rear wheels which necessitates a third differential being placed between them. This is usually enclosed in a housing bolted to the transmission and driven by a chain from the main transmission shaft. A typical construction of this kind is shown in Fig. 264.

CHAPTER XXVI

RUNNING GEAR

The parts of a motor vehicle not included in developing and transmitting power are classified under the general heading of running gear. This includes such parts as frames, springs, axles, wheels, brakes, steering gear, etc.

Frames. — The frame is the skeleton of the motor vehicle to which all other parts are directly or indirectly attached. Most frames manufactured for trucks and cars employ pressed steel side members which are of channel section. The cross members and side members are riveted in order to make tight joints and reinforcing plates are used to secure additional stiffness. Such parts as spring hangers are riveted to the frame. The side members are built with sufficient depth at the center to carry the load between the axles without bending and in some cases truss rods are used on cars or heavy trucks having long wheel bases. Since there is a tendency to bend the frame at the center the top part of the channel members will be under compression. For this reason holes must not be drilled in the top part of frames since these would weaken the members at the point of greatest stress, often resulting in sagging or complete buckling.

In addition to the cross members bracing the frame they often support a sub-frame to which the engine and sometimes the transmission are bolted. This gives the necessary flexibility of support for these units reducing the distortion due to uneven roads to a minimum. Sub-frames are not necessary when unit power plants are used supported by the main frame at three points.

Springs. — The frame is attached to the axles by springs which reduce the road shock transmitted to the axles by the wheels thus protecting the units supported directly by the frame. It is necessary that the springs be both strong and resilient and for this reason the built up or laminated leaf spring is universally used on motor-propelled vehicles.

The action of the spring leaves may be compared to a deck of cards. When held at the center and the ends bent up the cards slip on each other. The outer cards slip the most since they must conform to a curve of greater circumference than the inner ones. When

the pressure on the ends of the deck is released the cards spring back to their original position. If a solid piece of card-board of the same size as the deck were used bending would cause it to buckle, since its layers could not slip on each other. Therefore, the flexibility of a spring depends upon the number of leaves composing it and when pressure is applied at its ends the leaves slip on each other to conform to the changed radius of curvature. For this reason some lubricant must be placed between the spring leaves.

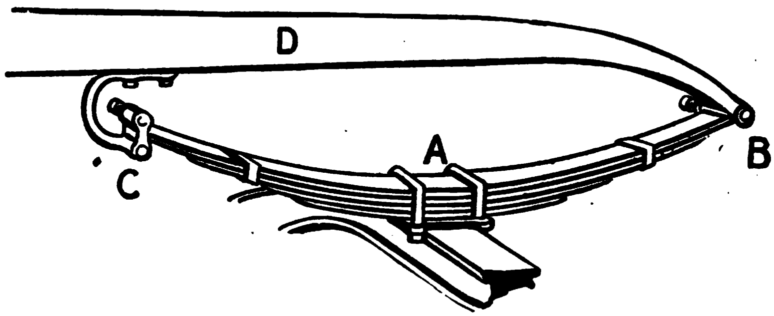


Fig. 283 — Semi-elliptical spring

The semi-elliptical spring (Fig. 283) is clamped at its center *A* to the axle by a spring saddle clip. One end of the spring is generally bolted to the frame as at *B* while the other end is attached by means of a spring shackle which allows it to move sufficiently to compensate for the elongation of the spring, when compressed.

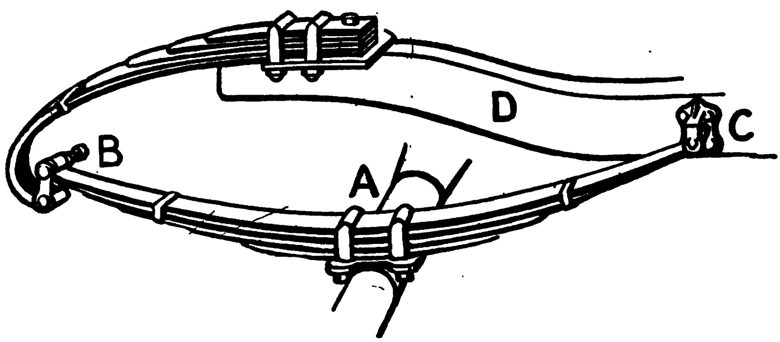


Fig. 284 — Three-quarter elliptical spring

The three-quarter elliptical spring (Fig. 284) is clamped to the axle in the usual manner at *A*. One end is bolted to the frame at *C* the other being rigidly held by spring saddle clips to the frame *D*.

A spring shackle bolt *B* holds the two members of the spring together allowing enough movement to compensate for the elongation of the main leaves when the spring is compressed.

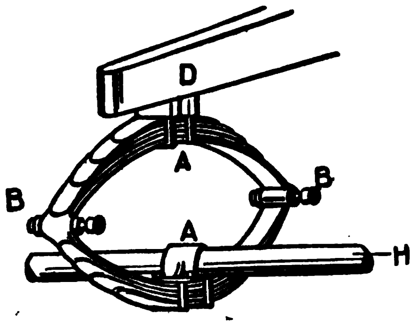


Fig. 285 — Full elliptical spring

The full elliptical spring (Fig. 285) is attached rigidly to both the axle and frame at points *A* in the usual manner. Spring shackles are not necessary since both top and bottom members will elongate the same amount when compressed. This type of spring is little used on automobiles because the springs cannot be used to transmit the driving effort to the frame due to their method of attachment.

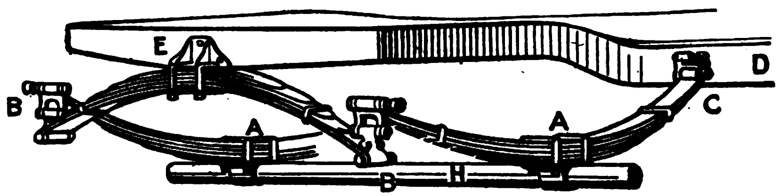


Fig. 286 — Platform springs

The platform spring construction (Fig. 286) is a combination of three semi-elliptical springs arranged as shown and used for attaching the frame to the rear axle only. The front ends of the two lower springs are bolted to the frame as at *C* their rear ends being attached to the third spring by the double shackles or ball-and-socket connections *B*. This spring is rigidly fastened to the frame at the center of the rear cross member *E*.

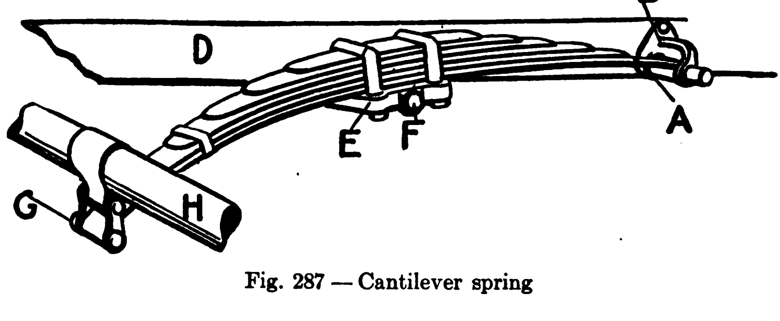


Fig. 287 — Cantilever spring

Figure 287 shows a cantilever type of spring. It does not differ much from the semi-elliptical spring in construction being built up in the same way, but made flatter and heavier. However, it is attached quite differently since the front end *A* is free to move in a shackle *B* bolted to the frame. A saddle *E* is clipped about the spring at or near its center and is pivoted on the pin *F* attached to the frame. The rear end *G* is fastened to the axle *H* by a shackle allowing free movement of the spring or it may be attached rigidly at this point. The action of this spring is similar to a spring-board and when running over rough roads permits the axle *H* to oscillate up and down.

Axles. — The springs are attached to the axles which support the weight of the car. There are two types of axle construction, the dead axle which remains stationary and the live axle which revolves, driving the wheels.

Dead axles are used for front axles on two-wheel drive machines and for rear axles when the final drive is by chain and for front and rear when internal gear drive to the wheels is used as on the Nash trucks.

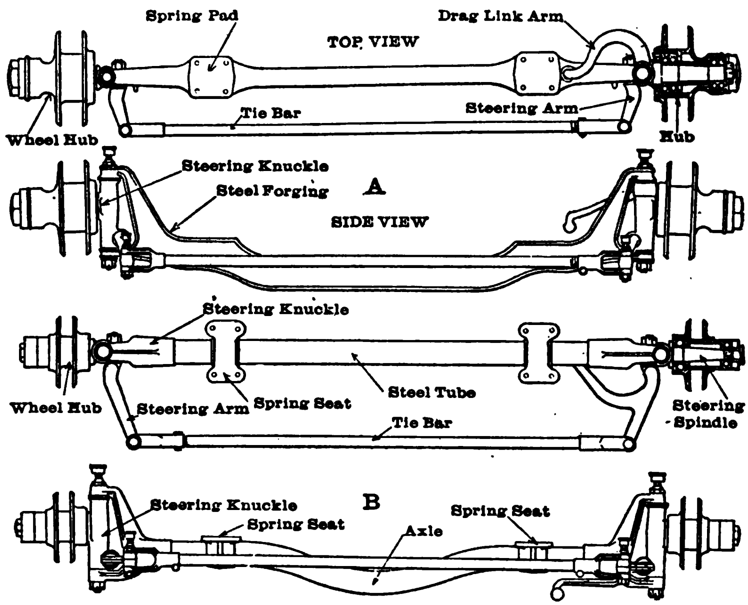


Fig. 288 — Front axles

Figure 288 shows typical front axles. Dead axles may be tubular (*B*) or " I beam " (*A*) section, the latter being a very common construction for front axles. " I beam " axles are generally drop-forged

from a single piece of steel, spring seats being an integral part as shown.

Live axles are always split into two parts each of which is driven by one of the differential gears. A housing completely encloses axles and gears protecting them from water, dust, and injury. There are three types of live axles; the full-floating, the three-quarter floating and semi-floating.

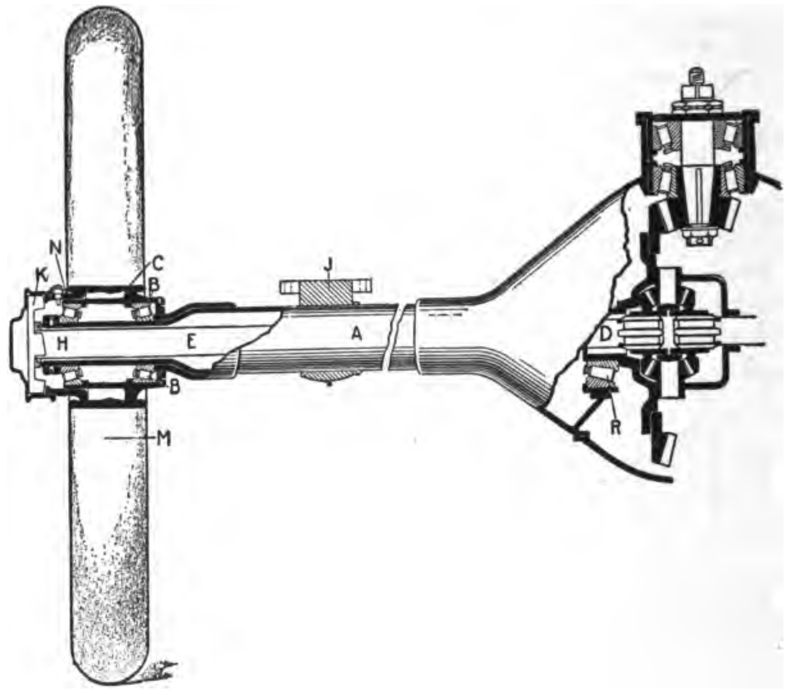


Fig. 289 — Full-floating axle

Figure 289 shows the construction of a full-floating live axle. The wheel *M* is supported by two bearings *B* running directly upon the axle housing *A*. The axle shaft *E* is fastened to the wheel hub flange *N* by means of the coupling *K* through which the rotary motion of the axle shaft is transmitted to the wheel. The axle shaft may be removed from the housing without disturbing the wheel by removing the coupling *K*.

The axle shaft *E* is not supported at either end by bearings and its position is maintained by the way it is attached at both ends. Thus the only strain on the axle shaft is that of driving the wheels and for this reason is known as a full floating axle.

Figure 290 shows a three-quarter floating construction of live

axle. The wheel M is supported by the single bearing B which runs on the axle housing A. The axle shaft E is rigidly keyed to the hub N thus maintaining the alignment of the wheel. This prevents the axle shaft from being removed without first removing the wheel. As in the full-floating type the axle shaft is not supported by bear-

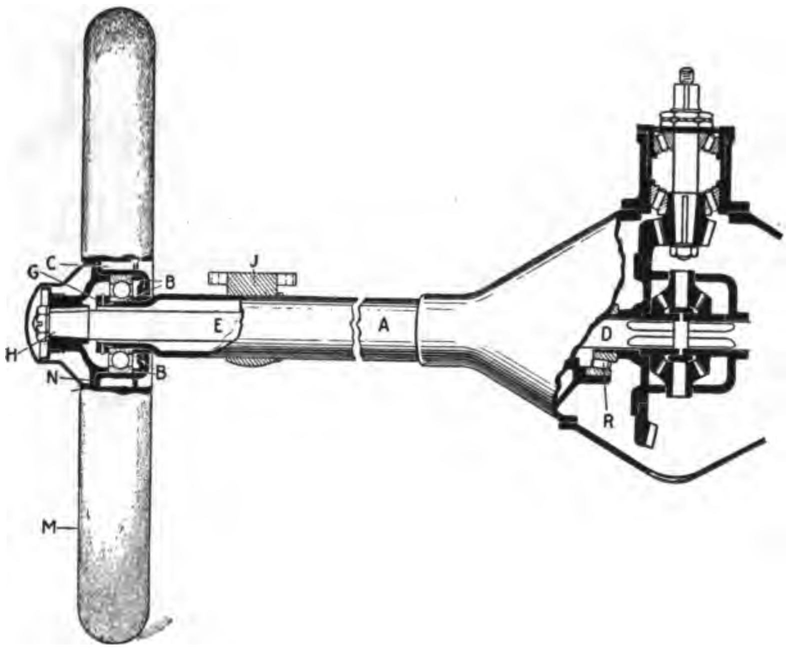


Fig. 290 — Three-quarter floating axle

ings at either end but differs in the type of bearings employed and method of attachment to the wheels. For this reason it is called a three-quarter floating axle.

Figure 291 shows a semi-floating construction of live axle. The inner end of the axle shaft D is sometimes fixed to the differential gear or else prevented from moving endwise by a collar on the axle shaft. The hub K of the wheel M is keyed to the outer end H of the axle shaft as in three-quarter floating type. The axle housing A supports a bearing B which is placed **inside** its outer end. Both the wheel and bearing B must be removed in order to withdraw the axle shaft. This arrangement results in the axle shaft E supporting the weight of the machine in addition to transmitting rotation to the wheels. For this reason it is called a semi-floating axle.

Wheels. — Wooden automobile wheels are nearly always of the artillery type, that is, the spokes at the hub are tapered so they

wedge together in a solid mass which gives great strength. These wheels are made of second growth hickory and flanges are bolted to both sides of the wheel hub (Fig. 292) for reinforcement.

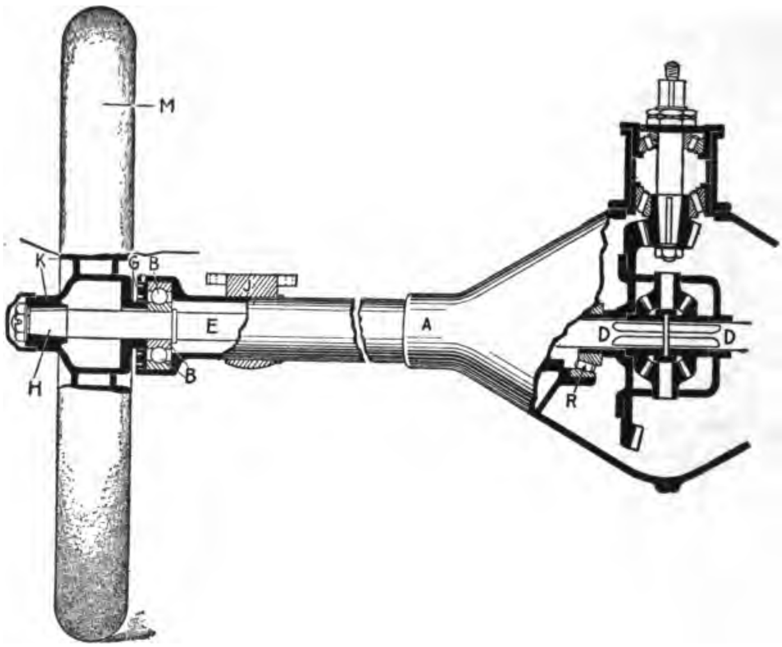


Fig. 291 — Semi-floating axle

The great advantage of the wooden wheel is that it has a certain amount of natural spring which absorbs some of the road shock. Wooden wheels are light but strong and can sustain heavy loads. However, they often break when side thrust is transmitted to them such as occasioned by the machine skidding around a corner. To make the wheels stronger, particularly their resistance to side thrust, they are generally **dished.** This is accomplished by setting the spokes at a slight angle with the axle which results in the plane of the rim, being outside the plane of the hub. Greater resiliency is also obtained in this way since the road shocks are not transmitted radially to the hub as would be the case with the ordinary construction. Wooden wheels are affected by dampness and must be kept well painted.

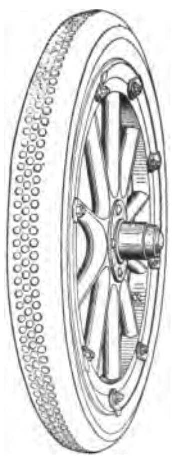


Fig. 292 — Artillery Wooden wheel

On heavy trucks, cast steel wheels are used

in which the spokes, hubs, and rim are all cast in one piece their form being very similar to the artillery wood wheel. These wheels are very strong but have the objection of being heavier for the additional strength obtained.

Steel wheels may also be constructed without spokes, a solid disc of metal joining the rim and hub. These wheels are made of both cast steel and pressed steel.

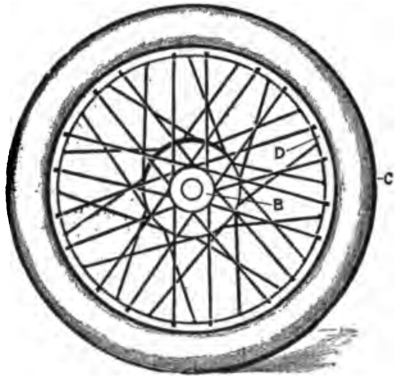


Fig. 293 — Wire wheel

In order to obtain light weight without sacrificing strength, wire wheels were adopted of a construction somewhat similar to those used on bicycles (Fig. 293). The load is not carried by the spokes under compression as in the wooden wheel, but by those under tension, all the spokes between the hub and the top of the rim carrying the load. These wheels are very flexible and absorb a great deal of the road shock. Side thrust is taken up in this type of wheel by the staggered arrangement of the spokes.

Brakes. — Brakes and their operating mechanism are very important parts of a motor vehicle. They may be classified under two general headings, the external contracting and the internal expanding. *A* and *B* (Fig. 294), show typical constructions of internal expanding brakes. *C* and *D* show typical constructions of external contracting brakes.

In the internal expanding brake, shown at *A*, the shoes faced with friction material are hinged at a common point as shown, their free ends being attached to a lever arm by toggle linkage. When the lever is moved to the left the shoes are forced outward against the brake drum. Another construction is shown at *B* which employs a cam to separate the free ends of the shoes. In actual construction, springs (not shown) are used to disengage the shoes when the pressure on the lever is released.

In the external contracting type shown at *C*, the brake band lined with friction material is attached to a double bell crank lever so that when pulled to the left the band is contracted on the brake drum. Another method of controlling the contraction of the brake band is shown at *D*. In this construction, an adjustment is provided to compensate for wear on the friction material. In actual construction, springs are used to hold the brake band away from the

drum and prevent it from dragging when released. The brake drums may be either attached to the wheels or to the drive shaft.

Figure 295 shows a typical construction of shaft brake used on the F. W. D. trucks. When a brake is placed on the drive shaft, the breaking effect is transmitted equally to the wheels through the power transmission units. However, such a brake does not overcome the differential action and skidding may result.

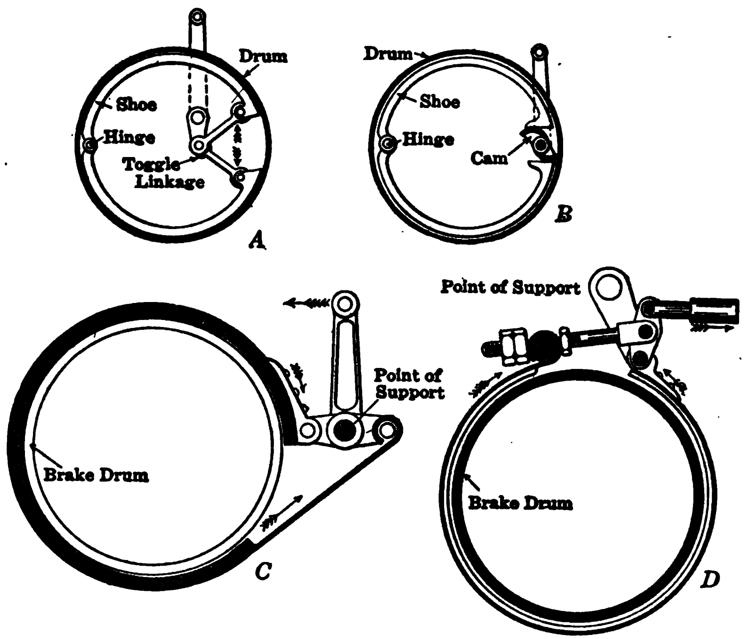


Fig. 294 — Types of brakes

When the drums are on the wheels the same drum is used for both external and internal brakes, the usual arrangement being to use the contracting brake for service and the expanding brake for emergency. Figure 296 shows this arrangement. Two internal brakes are sometimes used eliminating the contracting brake, because of the protection from dust and water thus obtained.

Some method of equalizing the pull transmitted from the brake pedal or lever to the brake drums on the wheels is necessary, since an unequal braking on the wheels will cause the machine to skid. This is accomplished by the use of brake equalizers.

Figure 297 shows a typical arrangement of brake rods and equalizers. The foot pedal controls the external contracting brakes and the emergency lever, the internal expanding brakes. When the

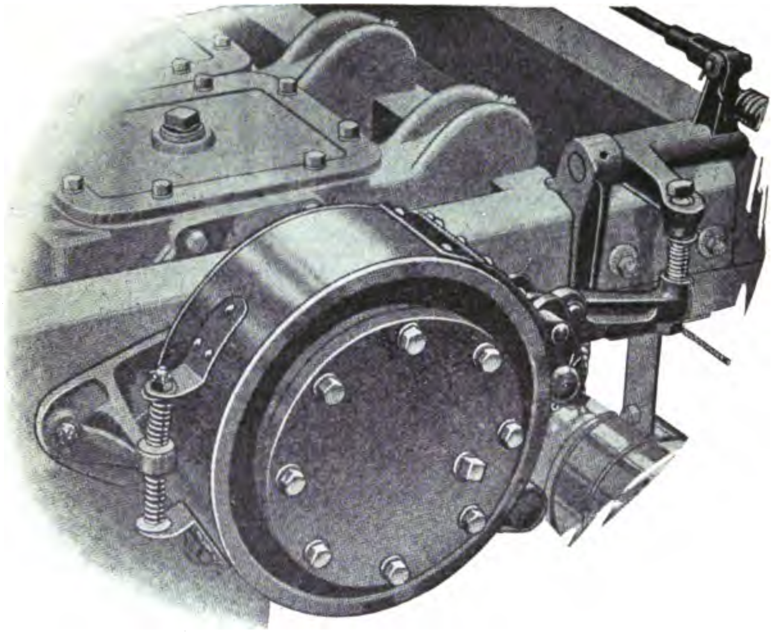


Fig. 295 — Shaft brake

foot pedal is depressed, rod *H* is pulled forward causing the shaft *X* to turn, pulling equally on the rods *L* and *K* which control the brake

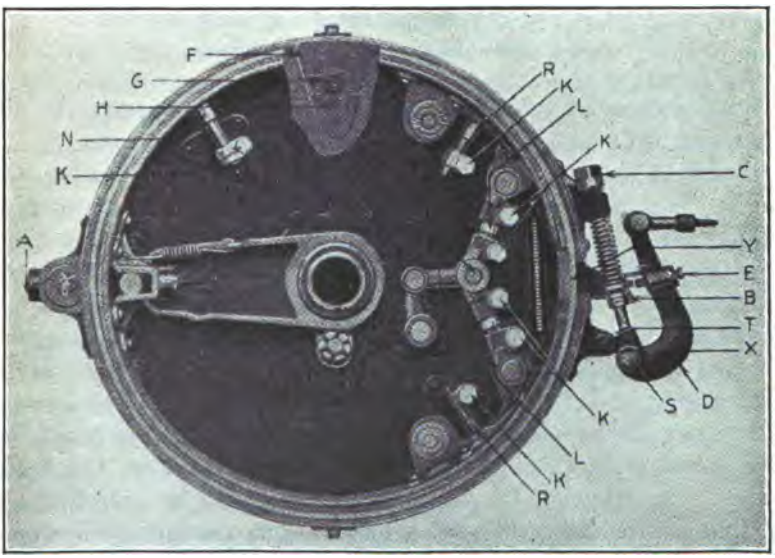


Fig. 296 — Typical wheel brake

levers *E*. If one brake is worn more than another, the breaking will not be equal unless compensated for by adjusting the brake shoes or by using a shorter rod between *X* and *E*. The latter is accomplished by screwing the yoke at *E* further up on the rod. The operation of the equalizer on the emergency brakes is identical.

The troubles which are usually experienced with brakes are: unequal braking, grabbing (usually on one brake), dragging, and slipping.

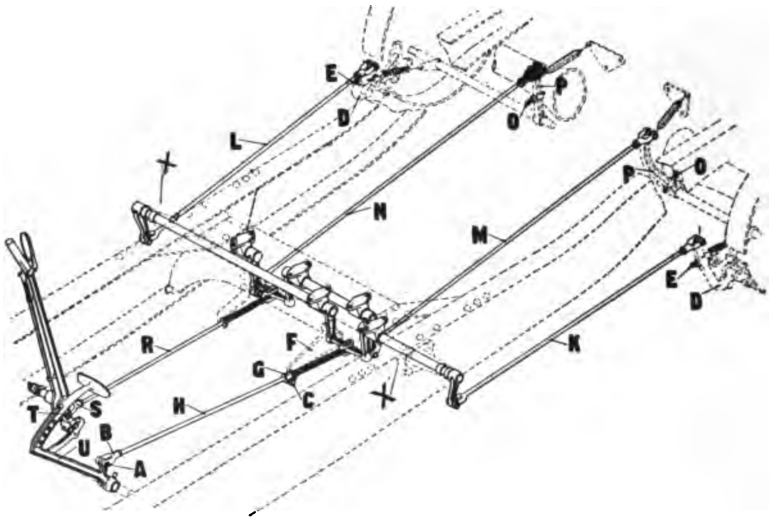


Fig. 297 — Brake rods and equalizers

To overcome unequal braking, the brake equalizers may be adjusted as just explained or the brakes adjusted at the drum.

Grabbing may be the result of the condition of the friction surfaces. This trouble is more apt to be experienced with external brakes because of their exposed position. It can usually be overcome by thoroughly cleaning and treating the friction material, the treatment depending upon the kind of material used. When one brake grabs it nearly always results from one equalizer rod being too short or the opposite rod being too long.

Dragging brakes may result from the springs on the brakes not completely disengaging the brake bands or shoes when released, but it is more often the result of improper adjustment of the brake levers. In adjusting the equalizers care should be exercised not to take up the loose side, when loosening on the tight side would give the proper movement of the foot pedal. It is possible to

shorten the equalizer rods so much that the foot pedal or lever will be in its disengaged position when the brakes are still engaged. The same thing results when the rods *R* or *H* (Fig. 297) are shortened too much. If both brakes drag equally, the rods *R* or *H* should be lengthened.

Slipping often results from grease or oil getting on the friction material. It can be remedied by thoroughly washing with gasoline of kerosene. Worn out brake linings will cause the brakes to slip and should be relined before worn completely through. If the equalizer rods or brake rods *R* or *H* are too long, slipping will result when the pedal or lever is applied since sufficient tension will not be put on the brake levers *D* or *P*. The rods *H* and *R* should be short enough so that the brakes are tightened on the drums before the pedal is completely depressed or the lever pulled all the way back.

Stop screws are sometimes provided as shown at *O* and *E* (Fig. 297) to limit the motion of the brake arms. When making adjustments the setting of these screws must be correspondingly changed.

Steering Gear. — In order to change the direction of motion of a motor vehicle, the position of the steering wheels must be altered. These are usually the front wheels although some machines are steered by turning both the front and rear wheels. In a horse-drawn vehicle the front and rear axles are parallel to each other when it is moving straight ahead and the front and rear wheels are in alignment. When turning, the front axle is swung out of parallel with the rear axle, pivoting at a point mid-way between the front wheels. This requires a movable front axle with but a single point of support for the front end of the vehicle and such a construction would be impracticable for a motor vehicle. The great weight supported by the front axle prohibits its movement and an unstable condition would exist if the front axle were moved out of parallel with the rear axle. In order for the wheels to be moved while the axle is held rigid, each wheel is separately pivoted at either end of the axle. These pivoted ends are called the knuckles and are connected by a tie rod so that both wheels move together.

For a wheel to follow a curved path without slipping it must at all times be tangent to this path and perpendicular to the radius of curvature. Figure 298 shows the paths of the front and rear wheels of both a horse-drawn vehicle and a motor vehicle when changing direction. The front wheels of the horse-drawn vehicle remain parallel at all times since they are perpendicular to a common radius. The intersection of a line passing through the front axle with one passing through the rear axle locates the point about which

the vehicle is turning. In the case of the motor vehicle, however, the front wheels are not parallel when changing direction, since they are perpendicular to two different radii which both intersect a line passing through the rear axle at the point about which the vehicle is turning. The front wheels in this case are parallel with each other only when the steering knuckle spindles are in line with the stationary axle which will be when the vehicle is moving straight ahead.

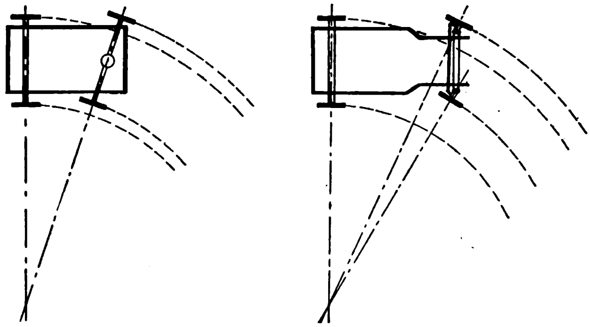


Fig. 298 — Steering arrangements compared

If the steering knuckle arms projected at right angles to the axle, the tie rod would cause both wheels to move through the same angle and be parallel at all times. This is prevented by inclining the

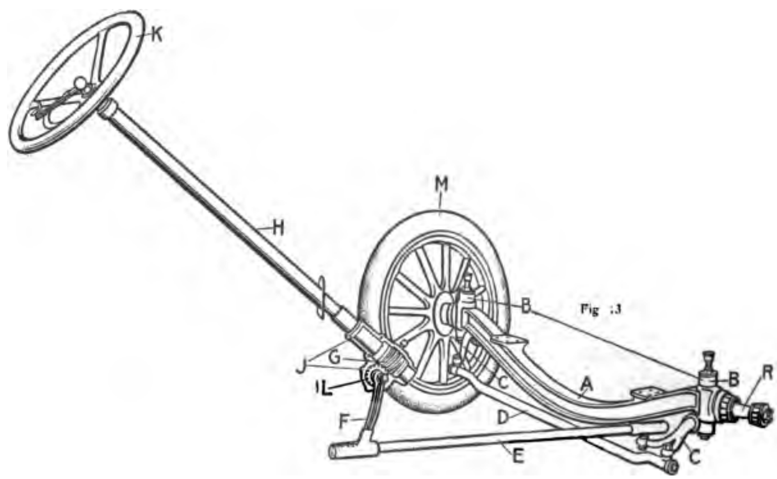


Fig. 299 — Steering apparatus

knuckle arms toward each other so that their center lines intersect at the center of the rear axle. In this way the inside wheel will be turned more than the outside one when changing direction.

Figure 299 shows a coventional arrangement of the parts composing the steering apparatus. The steering wheel *K* is fixed to the post *H* which is generally encased. The gear *G* is attached to the post *H* and meshes with the gear *L* which is keyed to a short shaft the other end of which is square and carries a lever or pitman arm *F*. The arm *F* is connected by a drag link *E* to one of the arms *C* of the steering knuckle *B*. The two steering knuckle arms *C* are connected to the tie rod *D* transmitting the turning motion to both knuckles. Each knuckle is pivoted on a king bolt which holds it in place on the axle forming a bearing about which it turns. The wheels are carried by the steering knuckle spindles *R* forged integral with the knuckle.

To make steering easier both the plane of the wheel and the axis about which the steering knuckle turns are inclined toward each other. This is called **camber** (Fig. 300). If a line passing through the axis of the king bolt strikes the ground at the point where the wheel rests, the wheel is pivoted so as to turn about its point of contact with the ground and consequently turns easily. However, the amount of inclination is never this great, usually being just enough to make the spokes of dished wheels vertical. Hence this pivot point generally falls outside the wheel's point of contact with the ground. **Caster effect** is obtained by canting the axle so that the bottom of the king bolt is approximately $\frac{1}{8}$ of an inch ahead of the top where the car is level. This tends to keep the steering wheels straight in the direction the machine is traveling. The resistance of the road to the motion of the machine tends to spread the front edges of the wheels apart. For this reason the front wheels are **gathered** slightly, the distance between the front edges being somewhat less than that between their rear edges.

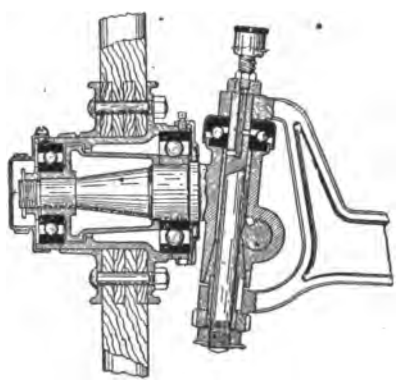


Fig. 300 — Camber

There are two types of steering gear, the reversible and the irreversible. The former transmits road shocks back through the steering gear causing the steering wheel to turn. The latter will not transmit road shocks through the steering gear, the steering wheel remaining steady. The type of steering apparatus will depend upon whether or not the gear keyed to the steering arm can turn the gear keyed to the steering post; and when worm gears of proper pitch are used this is not possible, an irreversible gear resulting. A

reversible gear results when bevel gears are used while the nut and screw construction may be either reversible or irreversible, depending upon the pitch of the screw.

To absorb the road shock especially when the irreversible type of steering gear is used, the ends of the drag link are enlarged and carry a spring thrust device. Within certain limits, movements of the steering wheel will cause compression of these springs preventing undue pressures being exerted on the steering knuckle arms or the pitman arm. The tension on these springs is adjustable and they are generally packed with grease and enclosed in a leather boot.

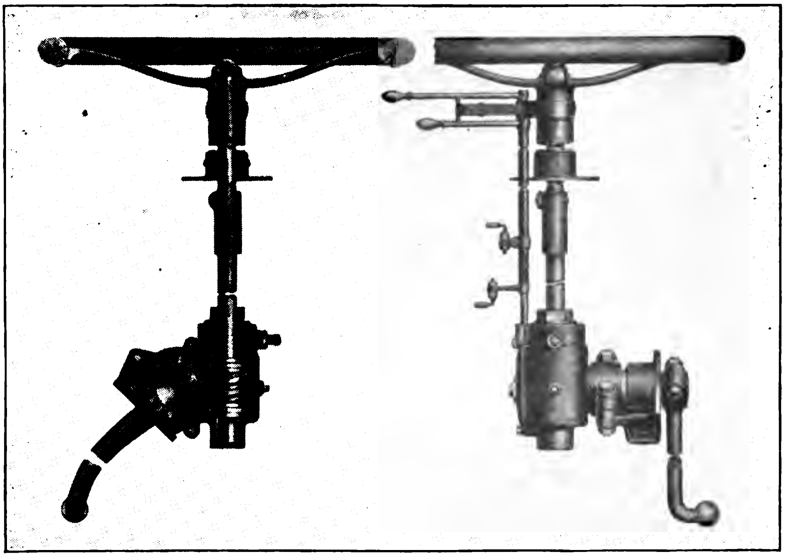


Fig. 301 — Irreversible steering gear

Figure 301 shows a typical irreversible steering gear which is employed on the Dodge car.

Bearings. — A bearing is necessary when one moving part of a machine turns on another. Energy is required to overcome the friction between moving surfaces in contact and depends upon the total area and the materials composing these surfaces. In the motor propelled vehicle it is important that the power generated by the engine should be delivered to the traction members with as little loss as possible. For this reason all engine bearings and those used in the various units of the power transmission system are designed to reduce the frictional loss to a minimum. There are three kinds of bearings in common use; plain, roller, and ball.

Plain bearings are almost universally used throughout the engine though they consume considerably more energy than the other types. However, they are necessary in order to obtain sufficient bearing surface to carry the heavy thrust resulting from the power impulses in the cylinders. The usual construction is to finish and polish the shaft or pin to a mirror-like surface, the surface against which it bears being of babbit or other low friction metal. Since there is considerable friction surface very good lubrication is necessary and special provisions such as oil grooves must be made to obtain the best lubrication possible. Plain bearings are also found on all parts of the machine where a loss of energy due to friction does not make any difference, such as on brake pedals, gear shift levers, spring bolts, etc.

Roller and ball bearings are used throughout the power transmission system, the former being used when the load is heavy or the end thrust is great and the latter where the load on the bearing is uniform and not heavy.

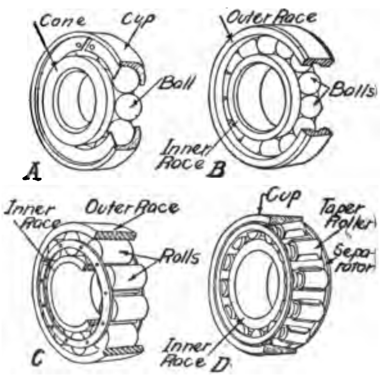


Fig. 302 — Anti-friction bearings

Figure 302 shows some commercial construction of ball and roller bearings. The ball bearing at *A* is a cup and cone design. This bearing has an angular contact and is capable of taking radial and light thrust loads. Such bearings are adjustable to a slight degree, as lost motion may be eliminated by forcing the cup or cone into more intimate contact with the balls. The ball bearing shown at *B* in of the annular type and is adapted only for radial loads and very light end thrust and is not adjustable. Since there is only a point contact in ball bearings, friction is a minimum requiring light oil and infrequent lubrication.

The roller bearing shown at *C* is provided with straight rollers and can take only radial loads. That shown at *D* employs tapered race members and correspondingly tapered rollers. Bearings of this type will carry not only radial loads but also resist end thrusts. This bearing is adjustable for wear by moving one of the race members into closer contact with the rollers. Roller bearings, having a line contact, are stronger than ball bearings but absorb more power because of the increased surfaces in contact. Therefore heavier oil and more lubrication is necessary than with ball bearings.

Figure 303 shows a typical installation of conical roller bearings on the front wheels and knuckles of a modern automobile. With this arrangement both the radial and thrust loads are carried.

Roller bearings are either solid or constructed as shown in Fig. 304. These rollers are constructed by rolling strips of steel into helices and are arranged in the bearing so that right and left helices alternate. This type gives increased flexibility reducing the transmitted strain resulting from sudden shock. In addition the arrangement of the helices is such as to keep the lubricant in continuous circulation over the entire bearing surface.

Fig. 303 — Roller-bearing installation

To space the balls or rollers in a bearing, cages or separators are used and are so constructed as to present the minimum amount of surface to the moving parts. These cages are usually made as light as possible and of soft material, such as brass.

Mufflers. — Mufflers are used on motor vehicles to reduce the noise of the escaping exhaust gases. This noise results from the sudden expansion of the gases when the exhaust valves are opened. It is not difficult to muffle the gases so that there will be but little noise, yet it is quite a problem to do it without producing a back pressure in the muffling device that will cause considerable loss of power. A muffler should offer minimum resistance to the passage of the gas, and means should be provided for not only breaking the entering stream into smaller streams but the capacity of the muffler should be sufficiently large to permit the gases to expand to nearly atmospheric pressure before they are discharged into the air. As the gas is delayed in its passage through the muffler from the cylinders to the open air its temperature is reduced, thus decreasing its expansion. Figure 305 shows several commercial designs of mufflers, all built on the same principle, but differing somewhat in construction.

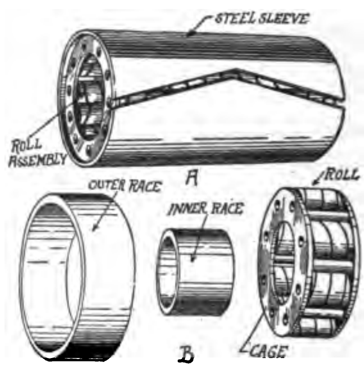


Fig. 304 — Hyatt bearings

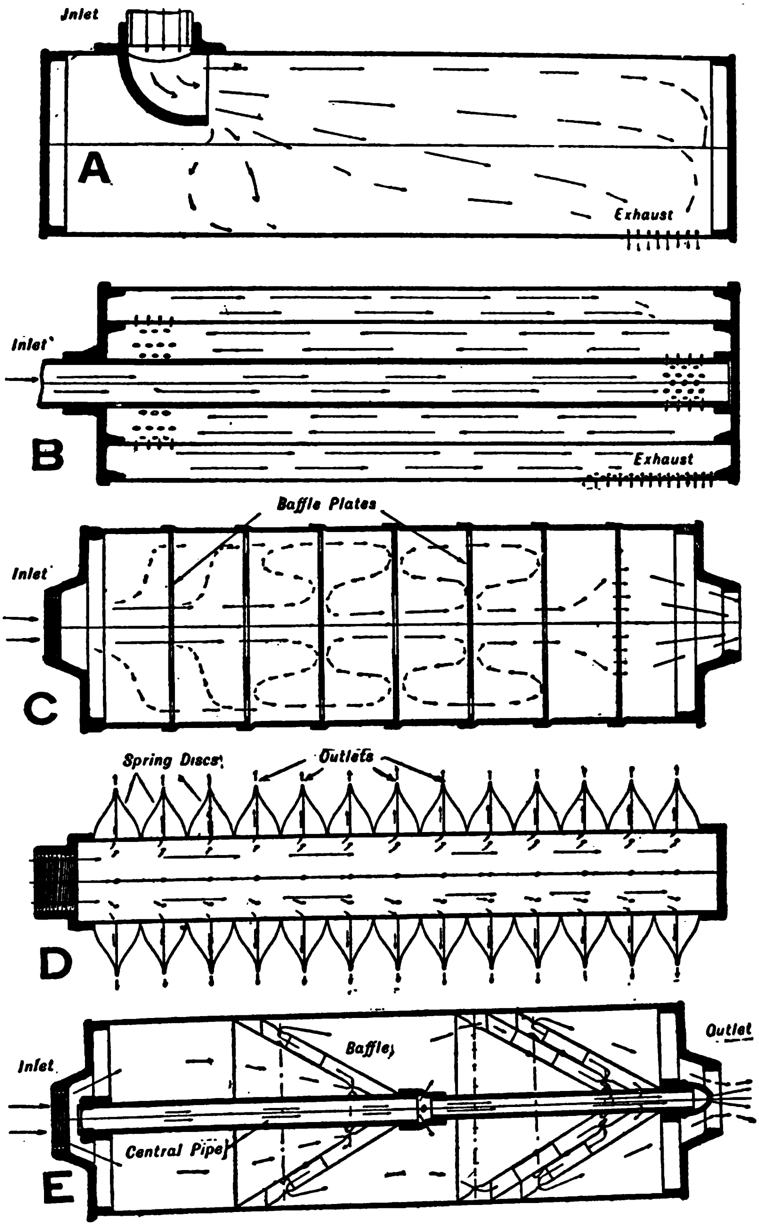


Fig. 305 — Typical mufflers

CHAPTER XXVII

TIRES AND RIMS

The wheels of motor vehicles are almost without exception provided with rubber tires. If the wheels were not properly tired the vibration transmitted to the machinery would soon cause it to shake itself to pieces. The great weight and speed of motor vehicles and the delicate construction of their machinery require additional protection to that afforded by the springs alone.

There are two types of tires in general use at the present time. These are the solid tire and the pneumatic tire. The former consists of a solid band of rubber, the resiliency or spring of the material itself being depended upon to absorb the road shock. This type of tire is used on trucks and other heavy motor vehicles where the speed is comparatively low. On lighter cars of higher speed solid tires would not be suitable since they would not absorb sufficient vibration. For this reason pneumatic tires are used. With the pneumatic tire not only the resiliency of the rubber but also that of the air with which it is inflated absorbs road shocks which would otherwise be transmitted to the machine. This is because a pneumatic tire is compressed when it strikes an obstacle in the road while a solid tire is only distorted.

The pneumatic tire in general use is of the double tube construction, being composed of two members, the inner tube and the shoe or casing. The inner tube is utilized to retain the air and is made of pure Para rubber approximately one-sixteenth of an inch in thickness. Such a tube would not be sufficiently strong to run directly on the road surface, necessitating the use of an outside casing of sufficient strength and wearing qualities to protect the inner tube. The casing is provided with some means of attachment to the rim so that when an inner tube is placed in it and inflated the casing will be held firmly in place.

Figure 306 shows a cross-section of a pneumatic tire. The main portion of the outer casing is composed of alternate layers of Sea Island cotton fabric and high-grade rubber composition. This composition is forced into the meshes of the cloth so that when vulcanized all the layers of fabric will be intimately joined together.

The fabric body is the part of the casing that gives it its strength, the number of layers of fabric used depending upon the size of the tire. Outside of the fabric body is placed a layer of very resilient Para rubber called the padding, which is thickest at the center of the tread and tapers off on either side as shown. The purpose of the padding is to give a certain amount of elasticity to the casing. On top of the padding and extending slightly beyond the center of the tread are placed several pieces of heavy fabric called breaker

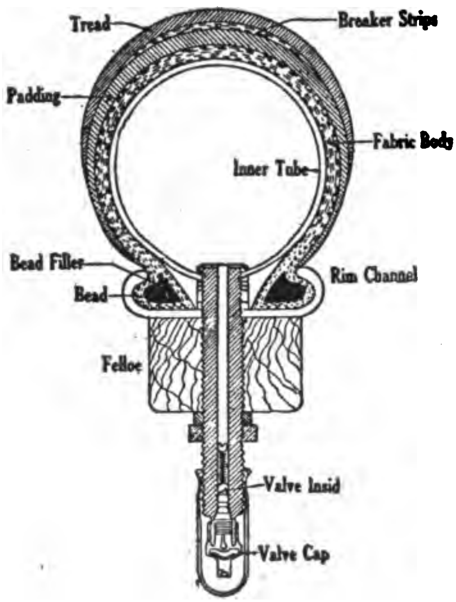


Fig. 306 — Cross-section of pneumatic tire

strips which offer resistance to any sharp object which penetrates the tread, tending to deflect it to one side, thus protecting the padding and fabric body. The outside surface is called the tread and is that part of the tire which is subjected to the greatest wear since it is in contact with the road surface. It must resist the abrasive action of the road and when used on driving wheels it suffers additional wear due to the tractive effort producing friction between the wheels and the ground. For this reason the tread must be of very tough rubber composition and differs from the material used for the padding and inner tube in not possessing so great a degree of elasticity. This is sacrificed in favor of great strength and resistance to wear which, of course, are essential.

There are two processes of building tires used by modern tire manufacturers. The first of these is known as the "moulded

process" where the tire is built up on a core and then clamped in a mould and vulcanized by steam. The other is known as the "wrapped tread process" where the tire is built up on a core as before and then tightly wrapped with strips of canvas and vulcanized.

Another construction of pneumatic tire is the cord tire. It does not differ materially in the way in which it is built up and vulcanized, but instead of layers of fabric being used the fabric body is composed of layers of cord, rubber composition being used as before. When the tire is vulcanized the layers of cord become filled with rubber and the whole mass is bound firmly together. Owing to its construction the cord tire cannot be as easily repaired as the fabric tire and it requires expert workmanship to repair a portion of a cord tire injured by a blow-out. Tires of this construction are much more resilient and give greater mileage than the stiffer fabric tire making them more desirable. There is also a cord-fabric tire in which the layers of cord composing the fabric body are replaced by layers of fine cord woven into a fabric. These tires are almost as flexible as the original cord tire but are much easier to repair.

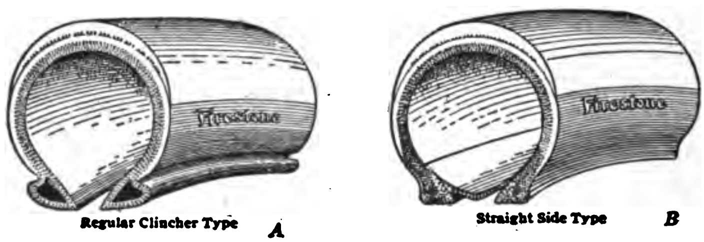


Fig. 307 — Types of casings

Two types of casings are supplied differing in their method of attachment to the rim. They are the clincher and the straight side or Dunlop types. At *A* (Fig. 307) is shown a clincher casing. The fabric is looped about a triangular insert of leather running along the edges of the tire and forming a bead. It is this bead which grips the flanges of the rim when the tire is inflated. This bead is either hard or soft, depending upon whether the tire is to be used on Q. D. or straight clincher rims. At *B* (Fig. 307) is shown a straight side casing. No bead is provided in this case the fabric being looped about strands of piano wire running around the inner edges of the tire. Since the steel wire does not stretch, the tire will be held snugly against the rim when inflated, the rim flanges preventing it from slipping off the rim sidewise.

Inner tubes are made from seamless rubber tubing of uniform thickness, the most resilient rubber obtainable being used. The tubing is cut the right length (which depends upon the diameter of the wheel) and the two ends are permanently joined by vulcanizing them together. Motor-cycle tubes are often made with two ends separately vulcanized in order to facilitate their removal from the casing. The only opening into the tube is where the valve stem is inserted which is an air-tight joint.

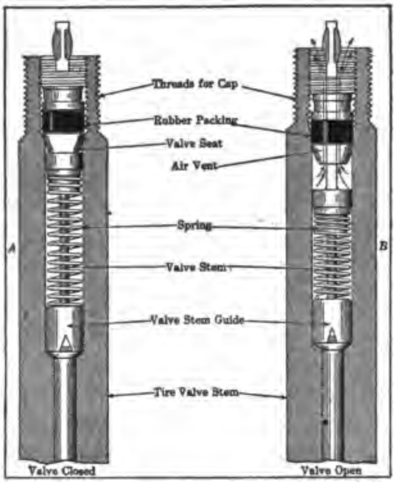


Fig. 308 — Valve

Air is introduced into the inner tube through a simple automatic valve (Fig. 308). The valve proper is held against its seat by a light spring and will only open when the valve stem is depressed by hand or when air pressure is forced against it in inflating the tire. When inflating a tire the air pressure on the inside holds the valve firmly in place whenever the incoming pressure is stopped. The valve must be screwed in tight enough to compress the rubber packing and make it swell out against the walls of the valve tube, forming an air-tight joint. The lower end of the valve tube or stem is inserted in the inner tube, a tight joint being obtained by screwing down a nut on the rubber tube and locking it in place, the joint being vulcanized and protected by a spring clamp.

The tread of the tire may be smooth or non-skid. The smooth tread has the disadvantage of poor traction and liability of skidding on muddy roads which has led to the development of the so-called non-skid tread. Non-skid or rough treads give better traction, wear longer, and to some extent prevent skidding.

Figure 309 shows several examples of commercial non-skid treads. It is customary to equip passenger cars with non-skid treads on the rear wheels and plain treads on the front wheels.

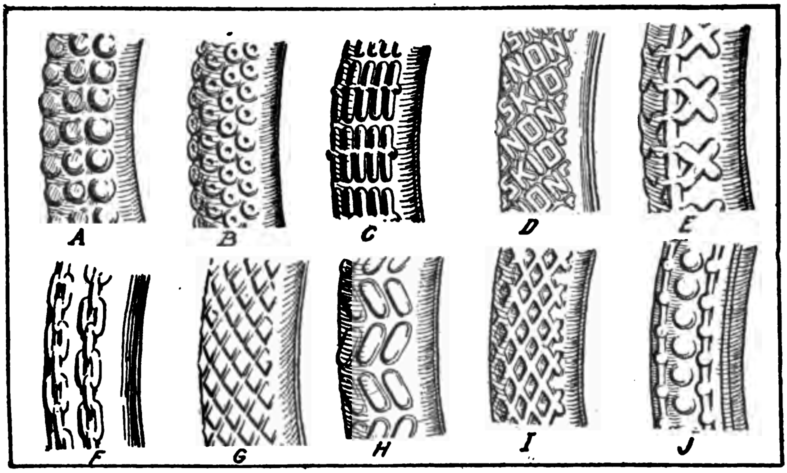


Fig. 309 — Some non-skid treads

The best preventive against skidding is the use of chains. Tire chains are made up of a series of short cross chains attached to two long chains, the ends of which are snapped together on the inside and outside of the wheels. Figure 310 shows the method of applying

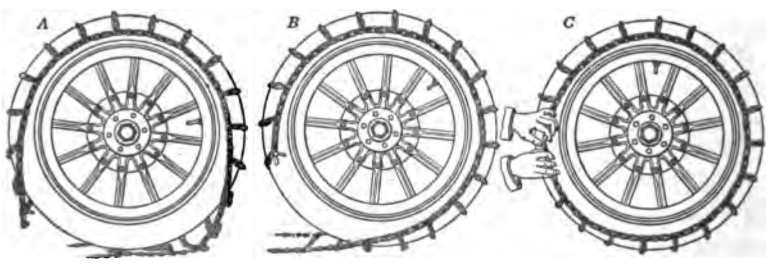


Fig 310 — How chains are applied

non-skid chains. Chains increase the traction and reduce skidding to a minimum. They should be applied both to the front and rear wheels to obtain the best results and should be supplied for use with both solid and pneumatic tires. Chains should be applied only when it is necessary to travel over roads that are soft and muddy and should be immediately removed when hard road surfaces are again encountered. This is because the cross chains chafe the tires, causing bruising of the tread and excessive wear.

There are two types or rims for pneumatic tires, the clincher and the straight side or Dunlop. The clincher rim may be plain one-piece, quick-detachable, or demountable. The plain clincher rim is very little used except on light cars, a typical construction being shown in Fig. 306. The straight side rim may be quick-detachable or demountable, the quick-detachable type usually being convertible, permitting either clincher or straight side tires to be used.

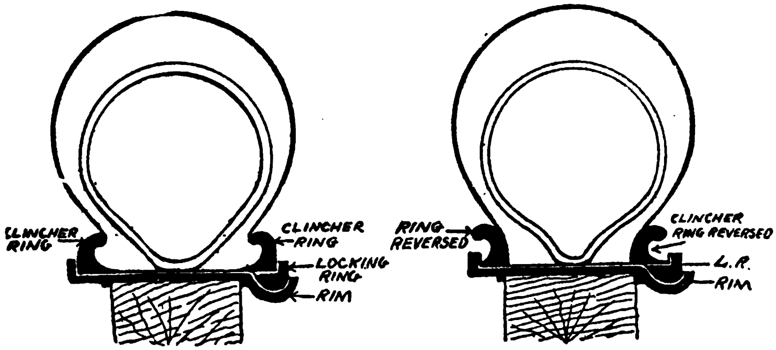


Fig. 311 — Rim forms

Figure 311 shows a quick-detachable rim with the clincher rim reversed to take both types of tires. To remove the tire from a quick-detachable rim it is only necessary to deflate it and press in the clincher ring, disengaging the locking ring, which is lifted out allowing the clincher ring to be removed. This permits one whole side of the tire to be pulled off the rim giving a quick and easy access to the inner tube for replacement or repair.

Numerous forms of demountable rims have been devised all of which are constructed along practically the same lines. The rim is held in place by a series of lugs or wedges which are bolted to the felloe of the wheel. By taking off the nuts holding these in place the whole rim may be slipped off the wheel and another substituted. The advantage of the demountable rim is that an entire spare casing, inner tube, and rim may be carried inflated and ready for use. In case of tire trouble on the road, tires can be quickly changed and the necessary tire repairs made at the end of the trip.

Demountable rims may be either quick-detachable or of split construction. The former permits the removal of the casing without taking the rim off the wheel while with the latter type it is necessary to remove the rims before the casing can be detached.

Figure 312 shows a quick-detachable demountable rim for clincher tires. The locking wedge is held in place by lugs bolted to the felloe of the wheel. When the retaining lugs are removed the rim may be pulled from the wheel, the side where the valve stem goes through the felloe being lifted off last.

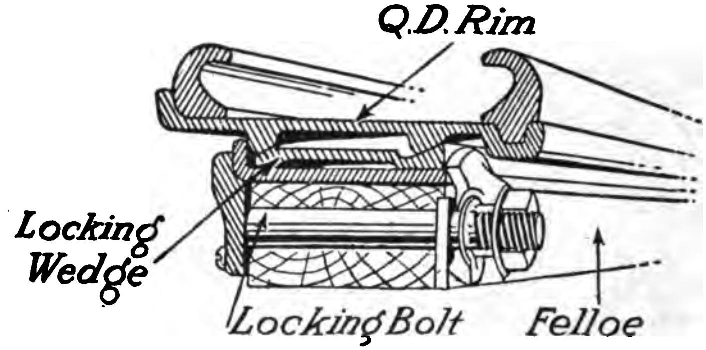


Fig. 312 — Demountable rim

On trucks and other heavy motor vehicles, pneumatic tires are not generally used because of the large size that would be required to carry the load. Since their speed as a rule is limited, solid rubber tires may be employed to advantage. These are moulded from some special rubber composition in one continuous ring and are usually provided with some form of re-enforcement at their base where they are clamped into the rim. Modern truck tires are quick-detachable or demountable and are usually held in place with wedges or flanges of similar construction to those used on pneumatic rims. Figure 313 shows a typical solid rubber tire on a demountable rim. It is re-enforced by a hard rubber base and clamped into place in its rim.

Fig. 313 — Solid tire

When the load on the rear wheels is particularly heavy, extra wide tires or dual tires are employed. Their construction does not differ materially from the single tire type the same method of attachment being employed but they are not so apt to slip sidewise on slippery roads.

When inserting an inner tube in a casing, care must be taken not to pinch or twist it, and to pull the valve stem through the rim straight. The following is the procedure when applying a casing to a

demountable rim. Clean out the casing and be sure it is dry. Shake some powdered mica or soapstone into the casing and turn it once or twice around to insure its whole interior being coated and then remove what remains. Insert the inner tube and apply the casing to the rim, putting the valve stem through the hole in the rim first. Assemble the rim and inflate the tire to about twenty pounds pressure. Then bounce the tire up and down turning it through two or three revolutions which permits the inner tube to straighten out and assume its natural position, preventing pinching or twisting of the tube or the valve stem being crooked. Finish inflating the tire to the proper pressure for its particular size.

The following table gives the proper pressures to which different sized tires should be inflated as recommended by leading tire manufacturers:

Diameter of tire Inches	Air Pressure in Tire Pounds per Square Inch
2½	50
3	60
3½	70
4	80
4½	90
5	90
5½	95
6	100

The air pressure in a tire increases when the machine is driven, due to the heat set up by the friction of traction. This must be taken into consideration when pumping up a tire before running. It is advisable, especially on a warm day, to release some of the pressure after running some distance. The pressure should first be tested and for this purpose a tire pressure gauge should be provided as part of the equipment of every machine having pneumatic tires.

The life of the tire depends directly upon the amount of care and attention that it receives. Probably no part of the machine is less looked after than the tires which are generally never given a thought until tire trouble results.

When returning from a run a careful inspection of the tires should be made and all cuts and holes should be immediately cleaned out and vulcanized. If there is any oil or grease on the tires it should be cleaned off, since oil attacks the rubber causing it to deteriorate. Inflate all tires fully. The dead weight of the

machine should never be allowed to rest on a deflated tire. Before starting out upon a run the pressure in the tires should be tested and any tires not pumped up to the required pressure should be inflated. Running on tires which are not properly inflated, causes them to become distorted, the amount of distortion depending upon the pressure in the tire. Such distortion, no matter how small, causes the layers of the fabric to become separated from each other and from the tread surface, resulting in the tire soon going to pieces. If the pressure is allowed to become so low that the tires spread out flat on the road, rim cutting may result and the inner tube will probably be ruined.

Fast driving and the sudden starting or stopping of the machine is very hard on tires, causing the tread surface to be worn where the wheels slide on the ground. When a machine turns a corner it tends to slide outward and if the speed is great enough the tread surface of the tires will be injured. Running in street car tracks or in deep ruts chafes the sides of the tires and must not be indulged in.

It is very important to have the front and rear wheels in alignment. If out of line the tire treads will wear in a very short time, a difference of less than an inch causing a grinding wear on the tires, especially the front ones.

The same size tires must be used on both pairs of wheels in order to equalize the traction. A plain tread tire should never be used on one rear wheel when a non-skid tire is on the other. In addition to excessive wear on the tires this also causes the differential gears to be unduly worn.

Inner tubes should be kept in a cool dry place away from oil, gasoline, and tools. It is best to keep them in a bag well dusted with soapstone. Spare casings should not be exposed to the rays of the sun. When a spare tire is carried inflated it should be encased in a tire cover.

Tire Troubles. — Probably the most common tire trouble on the road is puncture. When a tire is punctured not only the hole through the inner tube but also that through the casing should be repaired. The former may be patched or better still vulcanized while the opening through the casing may be filled with " tire dough " temporarily and later permanently vulcanized.

Blow-out is the most serious tire trouble that will be encountered and can only be repaired temporarily on the road. If an extra tire is not carried, repair the injured casing by inserting a new inner tube and using an inside and outside boot to strengthen the point in the casing where the blow-out occurred.

Small or thin cuts are often overlooked but should be immediately vulcanized when noticed. This is equally important when solid tires are used. A stone bruise is caused by running over the corner of a brick or other hard object which tears part of the tread surface from the tire. The loose rubber should be trimmed away and the hole filled up and vulcanized.

Sand blisters are caused by sand or grit from the road working in through overlooked punctures or cuts in the casing and collecting between the tread and fabric body. They should be opened by cutting in with a sharp knife and the accumulated dirt thoroughly cleaned out with gasoline. The opening should then be filled and vulcanized.

For making road repairs a tire repair kit should be carried containing cement, patches, tape, unvulcanized rubber, extra parts, etc., and the necessary tools. A small gasoline torch vulcanizer is a very valuable addition and all repairing of inner tubes should be done by vulcanizing rather than by using patches.

CHAPTER XXVIII

HOW TO DRIVE

Before starting an engine the driver should see that the gear shift lever is in neutral position and that the emergency brakes are set. The spark lever should be set at the proper position. If battery ignition is used it is best to have the lever in full retard position, as the spark will occur no matter how slow the engine is cranked. If magneto ignition is used the lever should be advanced slightly as a hotter spark is obtained in the advanced position than in the retarded. There is less probability of a kick-back when starting on magneto since it is necessary to turn the engine at a fairly high speed, approximately 100 R. P. M., to generate sufficient current to produce a spark.

The position of the throttle hand control should be set so that the throttle will be slightly open. In case the carburetor is equipped with an air-choking device this should be closed to cause a rich mixture for starting.

The ignition switch should be turned on and the engine cranked by pulling up quickly on the crank handle a quarter turn at a time. If an electric cranking motor is provided depress the starting button and advance the spark. If magneto ignition is used it is best to spin the engine. Crank the engine with the left hand if possible and stand in such a position that if the engine should kick-back the crank will not cause injury.

After the engine has started release the choke on the carburetor, advance the spark, and close the throttle to a position which will prevent racing. If a special dash adjustment is provided for regulating the mixture, allow this to remain in a position to cause a rich mixture until the engine warms up.

To Start the Car. — Allow the engine to warm up sufficiently to overcome missing and to run smoothly. When satisfied that the engine is running properly release the emergency brake. In case the car is on a grade apply the foot brake to prevent the car from moving. Press the clutch pedal all the way down and move the gear shift lever to first speed position. The clutch should be [illegible] to engage gradually and at the same time the throttle [illegible] sufficiently to prevent stalling, but not to cause

racing of the engine. If the foot brake has been employed it should be released as the clutch is engaged. After the clutch has fully engaged, the throttle should be opened sufficiently to accelerate the car to change to the next higher speed. The throttle should be controlled by the foot accelerator pedal. Once the car is in motion the driver must at all times keep his eyes on the road in the direction in which the car is moving or about to move when changing direction.

To Shift Gears (Increasing Speed). — Before starting a driver should practice moving the gear shift lever to the different positions and getting his feet and hands accustomed to the location of the foot pedals and hand levers. Then it will not be necessary to look away from the road in order to shift gears or in any other way to control the operation of the car. To change gears the clutch pedal should be depressed (it may not be necessary to push it all the way down against the floor boards) and the foot removed from the accelerator pedal at the same time. Move the gear shift lever from first to neutral position, pausing if necessary, and then move to second speed position. Engage the clutch immediately and open the throttle either with hand or foot control as soon as the clutch is engaged. The process of changing from second to third or from third to fourth is identical. Bear in mind that before each change is made the speed of the car should be accelerated. Care should be taken when changing from a lower to a higher speed that the car is moving at a sufficient rate of speed so that an undue strain will not be put on the engine. Practice alone in driving the particular apparatus will acquaint the driver with the necessary speed required to change from one gear ratio to another.

To Shift Gears (Decreasing Speed). — When it is desired to change from a higher to a lower gear ratio release the clutch and allow the hand or foot throttle control to remain open far enough so that the engine will speed up. Move the gear shift lever to the neutral position and again engage the clutch for an instant. Release the clutch immediately and quickly move the gear shift lever from neutral to the next lower speed position and engage the clutch immediately, opening the throttle by the hand or foot control.

Another method of shifting to lower gear ratio is to leave the throttle open and release the clutch just enough to allow it to slip and the engine to speed up. The gear shift lever should then be moved through neutral directly to the next lower speed position and the clutch engaged. This method does not require as much practice but is objectionable since it wears or burns the clutch facing.

To Stop the Car. — To stop the car the throttle should be closed,

the clutch released, and the brakes applied, all being performed at the same time. The amount of pressure applied at the brake pedal depends upon the distance in which the driver desires to stop the car. Before allowing the clutch to engage after the car has stopped, move the gear shift lever to the neutral position. If the car is to stand apply the emergency brakes. If the engine is to be stopped speed it up by opening the throttle just before turning the ignition switch to the " off " position. If the weather is cold use the choke when stopping the engine or set dash adjustment to give a rich mixture. This will make starting easier if the engine is started within a reasonable length of time.

Driving Suggestions. — In operating a car it is always best to alternate the service and emergency brakes rather than to use one continuously, to equalize the wear on them. When approaching a very steep down grade it is safest to move the gear shift lever to a lower speed position, closing the throttle and permitting the car to drive the engine. When the grade is not excessively steep the engine can be used as a brake with the position of the gear shift lever remaining unchanged. This will save the brakes and tend to cool the engine. The brakes should never be applied suddenly enough to slide the driving wheels except in cases of emergency. When a stop is to be made apply the brakes soon enough so that the motion of the car will be gradually diminished and brought to a stop at the desired point.

To avoid accidents on the road all rules and regulations governing the driving of motor vehicles on the road should be observed. When turning corners or approaching cross-roads warning should be given to avoid collision with other vehicles which may be hidden from the view of the driver. Before backing the machine the driver should be sure the road is clear. In manipulating the car the front wheels should never be turned by moving the steering wheel when the car is not in motion. This puts undue strain on the steering apparatus and will cause lost motion in the steering gear. If it becomes necessary to turn the front wheels of a car while it is standing still, they should be moved by applying force not only to the steering wheel but also by pulling the front wheels around.

When a car skids the tendency is for an inexperienced driver to apply the brakes and turn the front wheels in the opposite direction to that in which he is skidding. This should not be done as it only accentuates the skidding and the car may be ditched or skid into another vehicle or the curbing. When the machine starts to skid turn the steering wheels in the direction in which the car is skidding and partially close the throttle but not entirely, or it

will have the same effect as applying the brakes. When the car straightens out the power may be again applied gradually and the machine brought back to the center of the road. When skidding on narrow roads it is best to apply the power and steer for the center of the road. This will aggravate the skid for a moment but brings the machine around at an angle with the front wheels in the center of the road. The momentum of the car will cause the rear wheels to climb back on to the road again.

CHAPTER XXIX

ENGINE TROUBLES EXPERIENCED ON THE ROAD

If the engine will not start when the driver wants to take the machine from the parking space it is a very difficult matter to locate the trouble and it can only be located by a systematic search. It is always best to look over the ignition system first, then see if there is any gasoline at the carburetor. It will often take some time to find the trouble. However, if the engine once starts there is no reason for difficulty in locating the trouble as there will always be an indication which should point to the source of the trouble. The great difficulty with inexperienced drivers is that they do not reason out the matter carefully before attempting to remedy it. Also an inexperienced man usually looks for all troubles in the same place no matter what the indication. Nearly all the difficulties experienced with the engine arise from one of three sources; ignition, carburetion, or engine. These are outlined in the following table. The method of determining the trouble and remedy is explained at the end of the table. The trouble is located by the indication it gives the driver.

I. Engine Misses:
- A. Ignition.
  - 1. Plugs.
    - a. Short circuited.
    - b. Broken porcelain.
    - c. Too large a gap.
  - 2. Cable.
    - a. Broken.
    - b. Grounded.
  - 3. Instrument.
    - a. Dirty distributor.
    - b. Interrupter points (On Magneto).
- B. Carburetor
  - 1. Water in the carburetor.
  - 2. Dirt in the line.
  - 3. No pressure or no gas.
  - 4. Too lean a mixture.

- C. Engine.
  1. Cold.
  2. Valves sticking.

II. Back-Fires through the Carburetor:

- A. Ignition.
  1. Wired wrong.
  2. Timed wrong.
- B. Carburetor.
  1. Water in carburetor.
  2. Dirt in the line.
  3. No pressure or no gas.
  4. Too lean a mixture.
- C. Engine.
  1. Valve sticking (Inlet).

III. Engine Knocks:

- A. Ignition.
  1. Too far advanced.
- B. Engine.
  1. Carbonized cylinders (pre-ignition).
  2. Overheated engine.
  3. Loose bearings.
  4. Loose pistons.

IV. Engine Lacks Power:

- A. Ignition.
  1. Retarded spark
- B. Carburetor.
  1. Too rich a mixture.
- C. Engine.
  1. Exhaust valve not seating.
  2. Carbon in cylinder.
  3. Overheated engine.
  4. Lack of lubrication.
  5. Governor connections sticking.
- D. Brakes.
  1. Dragging.
- E. Clutch.
  1. Slipping.

V. Engine Overheats:
  A. Ignition.
    1. Retarded spark.
  B. Carburetor.
    1. Rich mixture.
  C. Engine.
    1. Cooling system.
      a. Fan belt off.
      b. No water.
      c. No circulation.
      d. Anti-freezing mixture.
    2. Carbonized cylinders.
    3. Lack of lubrication.

VI. Engine Stops:
  A. Engine and car stop gradually
    1. Trouble with fuel.
  B. Engine and Car stop suddenly.
    1. Mechanical trouble.
  C. Engine stops suddenly, car gradually.
    1. Trouble with ignition.

VII. Engine Wont Stop:
  A. Ignition.
    1. Cable.
    2. Switch.
  B. Pre-ignition.
    1. Carbon in cylinders.
    2. Overheated engine.

Now consider how each of these indications may differ so that it is possible to locate the exact source of trouble without first investigating. If a car has been on the road for some time and the engine misses it will either miss regularly in one or more cylinders or irregularly in all cylinders. If the former, the miss is due to ignition. The cylinder in which the miss is occuring can be easily determined by short circuiting each plug with a screwdriver. This is done by allowing the screwdriver to touch the central electrode of the plug and also the engine. When a plug is short-circuited, and it does not affect the operation of the engine, it shows that there was no spark jumping across the electrodes of the plug. If the cable

to this plug is disconnected and held a short distance from the central electrode of the plug from which it was removed, a spark will or will not jump this gap. If it does jump the gap it shows that the plug is short-circuited. The plug is either carbonized or the insulator is broken. If a spark does not occur place the cable near the engine and if a spark occurs it shows that the gap was too large at the electrodes of the plug. If no spark occurs it shows that the trouble is not in the plug but at some point ahead of this. If the engine is firing on all but one cylinder the trouble must be some place between the distributor rotor and the plug. First see if the distributor is dirty and then check up the cable to see if it is broken or grounded. One point to be remembered is that the parts of the magneto or battery ignition system incorporated in the instruments will effect the operation on all cylinders and there is no need of looking for the trouble there if only one cylinder misses. If every other cylinder to fire misses and magneto ignition is used, it is often due to the timing lever housing being jammed over to one side so that the interrupter points are opened only by one cam. In no case is it necessary to file the interrupter points to overcome a miss for the interrupter affects the operation on every cylinder and not one alone.

If the miss is irregular it is due to carburetor or fuel troubles. To locate the trouble open the pet cock at the bottom of the carburetor and if there is any water in the carburetor it will run out. This operation also shows whether the gasoline runs freely. If it does not there may be dirt in the line or no gasoline supply. After everything else has been tried to overcome the trouble adjust the carburetor to compensate for too lean a mixture.

When an engine is first started it will often miss. This is due to the engine being cold. Under no circumstances should time be wasted to overcome missing until the engine is warm. If an exhaust valve sticks it will cause the engine to miss as the gases will be forced out on the compression stroke. This is difficult to locate as it is a regular miss but usually results from an overheated engine.

If an engine back-fires when first started and does so continuously it is best to check up the wiring and timing of the ignition system. If the engine is running smoothly and suddenly starts to back-fire through the carburetor it is possible that the magneto coupling has slipped.

If there is water in the carburetor it may suddenly shut off the supply of gasoline and causes so lean a mixture that back-firing results. Dirt in the line or running out of gasoline would have the same effect. If back-firing into the carburetor is experienced in

addition to missing of the engine it is probably due to too lean a mixture. Back-firing also results from the inlet valve sticking or not seating properly.

If the engine suddenly develops a knock while in operation it may be due to the ignition being too far advanced for the condition under which the car is operating and the spark lever should be retarded. This will be noticed mostly when the car is under a hard pull such as on hills or when going through sandy roads. If the engine develops a knock, after having been run for a short while, which cannot be overcome by retarding the spark it may be due to carbon in the cylinders or an overheated engine both of which would cause pre-ignition of the charge. By pre-ignition is meant that the incoming charge when under compression is ignited due to the heat in the cylinder regardless of when the ignition spark takes place. Loose bearings and loose pistons will cause knocks but these should easily be distinguished from ignition knocks as they are present at all times.

If the engine shows a lack of power it may be that the ignition system is too far retarded due to the coupling driving the magneto having slipped. If too rich a mixture is used it will cause a loss of power but can easily be discovered by the black smoke which is given off at the exhaust pipe. Every precaution should be taken to locate the trouble when an engine shows a lack of power as it may be caused by the valves not seating properly, carbon in the cylinders, overheated engine, lack of lubrication, or the governor connection sticking. If lack of lubrication is causing the trouble it will soon lead to mechanical troubles such as scoring of the cylinder walls or burning out the bearings. An engine will often give an apparent indication of a lack of power due to the brakes dragging or the clutch slipping.

If an engine overheats it is best to check up and see whether or not the car is being operated on a retarded spark or if the mixture is too rich. The usual causes of the engine overheating are troubles experienced with the cooling system. Fan belts often break or slip, the water may have leaked out some place in the cooling system, or the circulation may be stopped in some way. If anti-freezing mixtures are allowed to remain in the cooling system in warm weather they will cause overheating of the engine due to their low conductivity of heat. Carbon in the cylinders causes the engine to overheat and is detrimental to its operation. If the engine is not lubricated properly it will overheat due to the additional friction of the parts.

If after the car is in operation the car and engine slow down

gradually the trouble is without doubt due to a lack of fuel or some trouble with the fuel system or carburetor. When the car stops under these conditions the engine usually back-fires into the carburetor just before the car stops.

If the car and engine stop suddenly it is an indication of some mechanical trouble such as a frozen bearing, broken connecting rod, or some other part which suddenly puts a brake on the movements of the car.

If the engine suddenly stops operating and the car continues to coast the trouble can be traced to the ignition system. A disconnected or broken wire usually causes the trouble.

If the engine will not stop when the ignition switch is thrown to the " off " position it is possible with magneto ignition that the cable between the magneto and switch is disconnected. That is, the switch does not connect the primary of the magneto to the ground. If the engine is overheated, due to lack of proper cooling or carbon in the cylinders, the engine will continue to operate due to the pre-ignition.

CHAPTER XXX

LUBRICATION

Lubrication is the principal problem in the care and upkeep of the motor vehicle. If proper lubrication is maintained a great part of the work required to keep a motor vehicle in good condition has been accomplished.

Before taking up the use of lubricants the purpose and reason for their use should be understood. Whenever any two metal surfaces rub against each other such as a shaft in a bearing or two gear teeth meshing together there is friction no matter how highly polished the

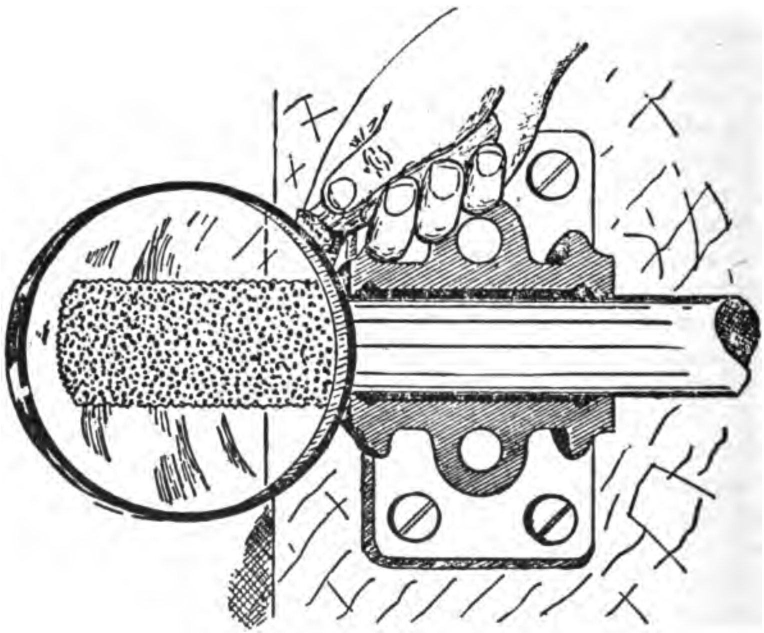


Fig. 314 — Magnified bearing surface

surfaces. If the surfaces were examined under a microscope they would appear to be covered with minute irregularities (Fig. 314). These irregularities if allowed to rub on each other would cause a loss of power and considerable wear and the heat set up would cause them to bind.

To prevent this condition some substance usually a layer of oil or grease called a lubricant is placed between the surfaces to separate them. The lubricant consists of a vast number of minutely dimensioned balls composed of fat and tied together by a mother liquor which maintains their separation. All the motion and rubbing comes between these balls of fat which are not hard like metal and, therefore, rub against each other with but little friction.

It is not enough to place the lubricating film between the surfaces, it must be kept there. To do this it is necessary to choose a lubricant that has the required properties to withstand the conditions under which it has to perform its duties. For his reason lubricants are rated in accordance with certain tests such as viscosity, flash point, fire point, cold point, and specific gravity.

Viscosity or fluidity of the lubricant is one of the most important things to be considered in its selection. If the lubricant flows too easily it will run out at the end of the bearing. Nearly all oils have good viscosity at ordinary temperatures but when heated they thin out too much and flow too freely. When a lubricant is to be used in an engine the viscosity should be measured at 100 degrees Fahrenheit, 200 degrees Fahrenheit, and 300 degrees Fahrenheit so as to determine a lubricant that is neither too heavy at low temperatures nor too thin at high temperatures.

Specific Gravity of the lubricant shows its body or density. This is important for it is necessary to have a lubricant that has sufficient body to withstand the pressure to which it is subjected.

Flash Point of an oil is the lowest temperature at which the vapors arising from it will ignite. When an oil is used in an internal combustion engine and thus exposed to severe heat it becomes imperative to use an oil of high flash point. This should not be much below 400 degrees Fahrenheit.

Fire Point of an oil is the lowest temperatue at which the oil itself ignites from the burning of its vapors. Since the fire point of an oil is always higher than the flash point it is of little value if the flash point is high.

Cold Point of an oil is the lowest temperature at which the oil will pour. This characteristic need only be taken into consideration because of its effect on free circulation of oil through exterior feed pipes when pressure is not applied. It also affects the lubricating qualities of the oil until it thaws out.

These specifications must be carefully considered in the selection of a lubricant and the correct lubricants to use will be specified in the Lubrication Tables in manufacturer's catalogues. When selecting engine oils it is necessary to consider carefully the fire point,

flash point, and viscosity. Bear in mind that an air-cooled engine requires a heavier oil and one of higher flash point than a water-cooled engine. It is also true that in warm weather a heavier lubricant is necessary than in cold weather.

It is well to consider the sources from which lubricants are obtained. The light oils such as cylinder oils are almost always mineral oils. The heavier oils for transmission are usually mineral oils made by adding animal or vegetable fats to thicken them. The greases are usually vegetable or animal substances of a soapy nature with mineral oils added to make them lubricants. Greases are usually of two kinds, cup grease and gear grease. The main difference is that cup grease will break down into soap and oil if heated while gear grease will not.

There are many methods used in lubricating an engine and only those most commonly found will be discussed. The parts requiring lubrication are the main crank shaft bearings, crank pin bearings, wrist pin bearings, cam shaft bearings, timing gears, cams, valve lifters and guides, pistons, piston rings, and cylinder walls. The following systems are employed:

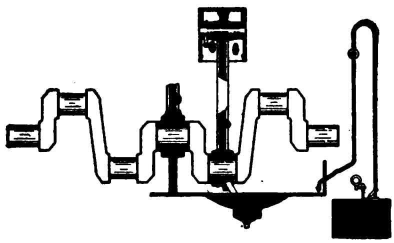


Fig. 315 — Splash system

Splash. — The oil is held in the crank case being supplied either by a mechanical oiler or direct from some outside source. As the engine turns over the lower ends of the connecting rods or dippers on the connecting rods strike the oil and splash it in all directions. This fills the cups that supply the main bearings. The crank pin bearings receive their oil through holes bored into the bearings. When the connecting rods dip, the oil is splashed up on the piston and cylinder walls. The oil which is splashed to the inner surface of the piston will drop off the lug (Fig. 315) and supply the wrist pin bearing. The cam shaft bearings and lifter rod bearings depend upon the splash for obtaining their lubrication. Thus all the parts are lubricated by the dipping of the connecting rods into the lubricant.

It is important not to let the oil level get too low. In putting

oil in the crank case it is also important not to have it too high. Too much oil will cause carbon to be formed in the cylinders which results in fouling of the spark plugs, pre-ignition, overheating, and knocking. It also causes a blue or white smoke at the exhaust which should not be confused with black smoke produced by too rich a mixture.

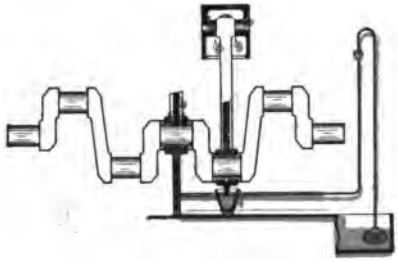


Fig. 316 — Splash with circulating pump

Splash with Circulating Pump. — This system is designed to overcome the difficulty experienced with over-lubrication as in the splash system. Oil is supplied from the reservoir or sump, by means of a pump to splash troughs (Fig. 316). These troughs are designed to hold only sufficient oil for proper lubrication and will overflow if too much oil is supplied to them. In this way the difficulty of over-lubricating is reduced to a minimum. In every other respect this system is identical with the splash.

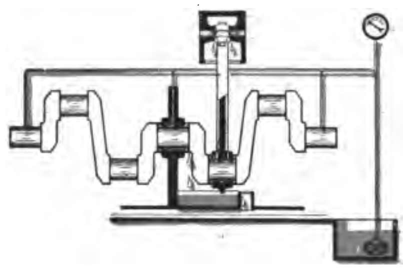


Fig. 317 — Force feed and splash

Force Feed and Splash. — Oil is forced by pump pressure direct to the main crank shaft bearings (Fig. 317). The overflow falls into the splash troughs in the crank case into which the connecting rods dip and splash oil to all other parts of the engine. A constant oil level is maintained in the splash troughs by an overflow to the sump or reservoir below, from which the oil is again circulated.

Force Feed. — The oil is forced by pump pressure direct to the main crank shaft bearings and then through holes drilled in the

crank arms to the crank pin bearings (Fig. 318). As the oil overflows from the crank pin bearings it is thrown by centrifugal force to the cylinder walls, piston walls, the wrist pin, and all other parts. There is no splash in this system as the connecting rods do not dip into oil. The overflow of the oil returns to the sump or reservoir and is again circulated.

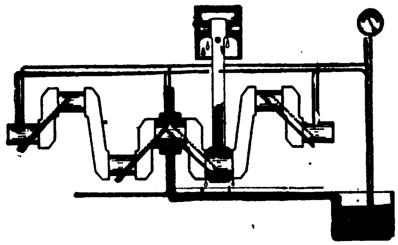


Fig. 318 — Force feed

Full Force Feed. — Oil is forced by pump pressure direct to the main crank shaft bearings and through holes in the crank arms to the crank pin bearings. From here it is led by pipes or hollow connecting rods to the wrist pin bearings (Fig. 319). The cam shaft is usually hollow and has its bearings supplied by the same

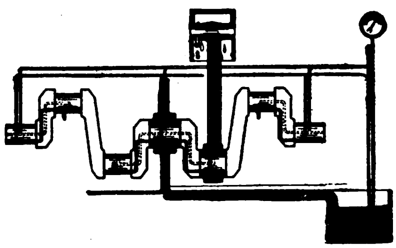


Fig. 319 — Full-force feed

pressure. The piston and cylinder walls are supplied by oil thrown from the lower ends of the connecting rods. In some cases the overflow of the oil from the wrist pins is used to assist in lubricating the piston and cylinder walls.

As it is continually necessary to add more lubricant to the engine it may be necessary to change the kind of oil used. If so, it is best to drain out the old oil and clean the crank case with kerosene and then refill with fresh oil. The reason for this is that oils do not always mix readily. When two oils are shaken or stirred up as in an engine, air bubbles will form. This causes a mixture of air and oil to be brought into contact with the surfaces instead of all lubricant.

Cleaning and draining of the crank case should also be done once a month or about every 1,000 miles of running. It should be done also at the end of the first 500 and 1,000 miles run with a new car. Drain out the old oil through the plug at the bottom of the crank case and refill with about a gallon of kerosene. If the engine has an electric starter turn the engine over with the starter for about fifteen seconds. If there is no starter the engine may be run for about the same length of time. This will thoroughly clean out the circulating system and the kerosene may now be drained from the crank case. It is important that all the kerosene be drained from the crank case as any that is left will mix with the new oil, reducing its lubricating qualities. In some engines such as the Wisconsin the splash partitions in the crank case will retain considerable kerosene and it will be necessary to remove the lower half of the crank case to drain it thoroughly. This removal gives a chance for the inspection of the pistons, connecting rods, main bearings, etc., and advantage should be taken of this opportunity. After the kerosene is thoroughly drained from the crank case the oil strainer should be cleaned and replaced and the crank case refilled to the proper level with fresh oil. Before starting the engine it is wise to turn it over several times by hand to fill the circulating system with fresh oil. If the oil circulating system on the engine is supplied with a pressure gauge, excessive pressure or no pressure at all at a car speed of fifteen to twenty-five miles an hour indicates plugging of the oil circulation system and should be investigated immediately. The same is true of the stoppage or irregular action of a sight feed if one is supplied. In the case of the White (Model T. E. B. O.) this latter trouble might be due to stoppage in the oil pump check valves which should be investigated immediately.

The proper level for oil in the transmission case is such that all the gears on the upper shaft dip one-half inch or so into the oil. The transmission case should be drained, cleaned with kerosene, and refilled every 5000 miles or about twice a year. The level should be inspected monthly.

A wet plate or multiple disc clutch should be drained and cleaned with kerosene once a month or every 1,000 miles. When cleaning with kerosene run the engine and disengage the clutch several times. Do not use too heavy an oil in the clutch as it will cause it either to slip, drag, or both.

Oil or grease may be used in the differential housing. The determining factor in many cases is leakage of the lubricant from the end of the rear axle onto the brake drums. If this is continuous and cannot be stopped by the use of a new felt washer in the rear

axle it will be advisable to mix some heavier grease with the lubricant recommended, to prevent this leakage.

A general rule may be given for the use of grease cups. Turn the cup till the grease is seen to start squeezing from the bearing. There are of course exceptions to the general rule such as when the grease might reach parts that would be injured by it or when the cup is so located that no grease can escape. However, as a general rule grease cups are turned too little rather than too much. Be careful to wipe off all excess grease as it collects dirt and grit which may work into the bearing and cause damage. It is also better to use oil in place of grease on brake equalizer slides and other exposed places as it is not so liable to pick up dirt and grit.

It must be remembered in handling grease cups that the threads are very fine and easily crossed. The cap must be held square with the threads when starting to turn it on. If the cap turns hard the threads are probably crossed. The cap should be backed off and a new start made. If this is not done the threads will be stripped and the cap spoiled. The same thing applies to grease guns which usually have fine threads on the cap.

As already stated gasoline and kerosene are used to wash out lubrication from any part and for this reason care should be taken not to over prime an engine. If too much gasoline is used when priming an engine it will wash the oil away from the piston and cylinder walls causing a loss of compression. This makes it very hard to start the engine and if it is started will often result in scoring the cylinders or pistons. This is because the oil in circulating to these parts will often require more time than it takes for the parts to heat up and expand due to the additional friction. The proper method of priming an engine is to fill the priming cup full and then open the cock and allow only this amount to flow into the cylinder. Do not squirt it in direct from the oil can.

The following lubrication "don'ts" will give some of the necessary points which must be carefully considered:

Don't forget that an air cooled engine requires heavier oil than a water cooled engine because of its higher operating temperature.

Don't think that oil never wears out.

Don't judge the viscosity of an oil at atmospheric temperature. Remember that when oil passes through the bearings it has a much higher temperature than the surrounding air.

Don't fill the oil reservoir above the correct level. Enough is sufficient, too much causes trouble.

Don't expect lubricating oil to perform the impossible task of correcting mechanical defects. Too much clearance between piston

and cylinder or bad and leaky piston rings will surely fill the cylinder with carbon even when the best lubricating oil is used.

Don't use a light oil when a heavy oil is required, under the impression that an oil must be light in order to reach the parts.

Don't use a heavy oil when a light oil is required, for instance as on ball bearings in the magneto.

Don't use grease which is not semi-fluid in transmission or differentials. After the gears have cut tracks in hard grease further lubrication is impossible and rapid wear will result.

Don't run the engine fast when a car is new and the bearings are tight. Wait until the car has made at least 500 to 1,000 miles.

Don't fill the reservoir by pouring oil into it through a dirty or sandy funnel.

Don't lose sight of the fact that the life of the car depends upon the proper lubrication of the parts.

Don't forget that lubricating should be done often and at regular intervals.

CHAPTER XXXI

CARE AND ADJUSTMENT

To keep motor propelled vehicles in proper running condition it is necessary that certain parts be inspected and adjusted at regular intervals. Besides these adjustments certain repairs will be outlined in this chapter which are likely to become necessary under running conditions. Repairs which require special tools and machinery, resulting from accident or other breakage, are not discussed in this book.

Testing Compression. — To test the compression on a warm engine each cylinder must be considered separately. Open the pet cocks on all the cylinders except the one that is to be tested and turn the engine over until the piston comes up against compression in that cylinder. If the compression is good the crank should resist being turned over and if the pull on the crank is released it should fly back as if moved by a spring. Hold the crank up against compression for ten or fifteen seconds and see if the gas in the cylinder leaks out relieving the pressure. The length of time that the cylinder will hold compression indicates the amount of leakage. Try the compression of each cylinder in turn and see if it is the same in all. Loss of compression is due to the gas leaking out of the cylinder and these leaks are of three classes:

1. Past various joints such as cylinder head gasket, valve cap, spark plug, priming cock, etc.
2. Past pistons and piston rings.
3. Past valves.

Leaks of the first class can usually be detected by the hissing sound of the escaping gas around the joints and may be located by running oil around these joints and watching for bubbles as the engine is turned by hand or run slowly. Leaks through the cylinder head gasket can be detected by the above method unless the leak is into the water jacket. This may be detected by the presence of water in the cylinders after the engine has been idle for some time or by listening at the radiator cap for the noise of the gas gurgling into the water.

Leaks of the second class should be tested for after determining that the leak is not of the first class by putting a couple of table-

spoonfuls of heavy oil in the leaking cylinder and determing whether the compression has been improved. If this does not improve the compression it shows that the leak must be past the valves. Such leaks may be due to improper adjustment of the valve tappets, to a valve sticking, or to a valve which is warped or does not seat properly. In the latter case the valve will probably have to be ground.

Adjusting Valve Tappets. — Most engines are provided with adjusting nuts for regulating the clearance between the valve stem and the push rod. The different instruction books and the Care and Adjustment Tables in the next chapter give the proper " cold " clearance for the different engines on the cars used in the service. When measuring valve clearance, be sure that the valve whose clearance is to be tested is in the closed position. If the piston of one cylinder is placed at top dead center on compression both valves will be closed and their clearance may be tested. Another good method is to turn the engine over by hand until one valve is wide open and then turn another full revolution. The valve will now be closed and the nose on the cam shaft will be pointing directly away from the tappet. After the valve is closed, select a gauge of the proper thickness and slip it between the valve stem and the push rod. Adjust the adjusting nut so that the gauge will just slip freely between the two and tighten the locknut. In tightening the nut, be sure that the adjustment is not changed and the nut is **tight.** Check the clearance after the adjustment is set. If a thickness gauge is not available one can be made of several thicknesses of paper remembering that the paper in this book is about 0.003 inch thick. In case the cold clearance is not known the clearance may be checked while the engine is hot. The engine should be run until thoroughly warm and the adjustment made to allow a perceptible amount of play. This should be just enough to show that there is play and no more. The object of this play is to allow for further heating of the engine, for a small amount of wear on the valve at its seat, and to insure that the tappet is not preventing the valve from seating. When valves are adjusted for cold clearance it is best to use this method of checking their clearance. If after checking the valve clearance the compression leaks past the valves they should be ground.

Valve Grinding. — To grind a valve first remove the valve cap or drain the radiator and remove the cylinder head cover. Lift the valve spring with a valve lifter tool and remove the valve spring retainer, lifting out the valve. Remove the spring and turn down the valve tappet adjusting screw so as not to interfere with the valve

stem. Clean the carbon from the valve and from around its seat. If a valve is very badly pitted, if the head is warped or out of line with its seat, or if shoulders appear on the face of its seat, the valve should be refaced by a mechanic with the proper tools before grinding. Place some waste or a piece of cloth in the gas passage and in the passage to the cylinder to prevent the grinding compound from getting into these places and place a little valve grinding compound on the face of the valve. This compound comes in coarse, medium, and fine grades. Unless the valve is badly pitted the medium grade should be used first and the grinding finished with the fine. Be sparing of the compound and do not plaster the rest of the valve head with it. The compound should be put on in a smooth coat. Put a light spring under the valve head when replacing it in its seat to lift the valve off its seat when the pressure used in grinding is removed. With a screwdriver or brace, turn the valve about a half turn first to the right and then to the left, exerting about three or four pounds downward pressure. At frequent intervals let the valve lift off its seat and turn it to a new position before reseating. Continue the oscillating motion as before until a silvery band appears completely around the valve. There should be no pits or breaks in this band and the grinding should be continued until this is accomplished. This band need not be over $\frac{1}{16}$ inch to $\frac{3}{32}$ inch wide. After the band is established a smooth finish should be given the surfaces using the fine grinding compound. Make sure that none of it gets into the cylinder, gas passages, or valve stem guide. Valve grinding requires patience and persistence to do good work. Be very careful in grinding valves not to interchange them nor to put the wrong valve in the wrong seat, as it will not make a gas tight joint. The exhaust valves being exposed to the hot gases will require grinding much more often that the inlet valves. After the valves are ground they may be replaced, the spring and spring retainer put in place, and the valve tappet adjusted.

Carbon Removal. — If carbon becomes excessive it causes overheating of the engine, lack of power, pre-ignition, and a tendency for explosions to continue after the ignition switch has been turned off.

The cylinders can be kept reasonably free of carbon by removing the spark plugs and introducing a tablespoonful of kerosene in each cylinder about once a week. The kerosene should be inserted when the engine is hot, and the best results will be obtained by placing it in the cylinders at night in order that it may have an opportunity to soften the carbon deposit before the engine is used again.

If the engine has been run for some time without cleaning out the cylinders it is well to pour about a pint of kerosene through the air intake of the carburetor with the engine hot and running at high speed and the spark lever fully retarded. Do not choke the engine with the kerosene but pour it in as fast as the engine will take it and run. After this operation place a tablespoonful of kerosene in each cylinder and allow the engine to stand idle for ten or twelve hours.

If an excessive amount of carbon has accumulated in the cylinders kerosene will not remove it. It can then be removed in one of several ways. It can be scraped out by removing the cylinder head casting or valve caps, it may be loosened and blown out through the exhaust by the use of a carbon removing chain in the cylinder, it may be dissolved out with a carbon remover, or it may be burned out with oxygen.

If the cylinder head is removable it is an easy matter to remove the carbon by scraping. Turn the engine over until the piston in the cylinder to be scraped is at top dead center on compression stroke. This prevents loose carbon from getting into the valve parts and reduces to a minmum the amount of carbon getting in between the piston and cylinder walls. All holes in the cylinder block such as water jackets and stud holes should be packed with waste.

It is very difficult to remove carbon by scraping through valve cap holes. Special scrapers are required for scraping the cylinder head and the top of the piston. They must be worked back and forth over the surface with considerable pressure until the scratching sensation stops and the tool seems to glide freely over the surface. Be very careful not to scratch the surface. Blow out the carbon at frequent intervals with an air hose if possible or with a hand bellows if compressed air is not available. Be sure to scrape the entire inner surfaces of the combustion space and do not leave any jagged patches as they will become incandescent and cause pre-ignition. Continue scraping until the air does not blow out any more carbon dust. The same precautions should be taken regarding keeping the valves closed and dust out of the cylinders as when the cylinder head is removable.

After carbon has been scraped and as much as possible blown out, pour about a half a glassful of kerosene into the cylinder and apply the air blast. This should remove the remaining carbon. Another half a glassful should now be poured into the cylinder and the engine turned over several times by hand. This will remove any carbon which may have worked down between the piston and the

cylinder. The crank case should now be drained and washed with kerosene and refilled with fresh oil.

When using a carbon removing chain it should be placed in position on top of the piston through the exhaust valve cap opening. Remove the spark plug and inject into the cylinder about two tablespoonfuls of kerosene. The chain used should be joined at its ends and should be made of spring steel or piano wire which is hard but not brittle. The links should not exceed $\frac{3}{8}$ inch in diameter and the total length should be about twelve inches. Screw back the valve cap leaving out the spark plug and run the engine for several minutes. The carbon loosened by the chain will be blown out.

To use liquid carbon remover, remove the valve caps and turn two cylinders to top dead center. This should be done when the engine is warm. Put the carbon remover in these two cylinders allowing it to remain for about an hour and then remove it by syphoning. The combustion chamber should now be dried out as well as possible with a dry cloth. Repeat the same process in the other pair of cylinders. This method is not as effective as scraping or burning out the carbon.

In burning out the carbon one piston is brought to top dead center on compression, the spark plug and one of the valve caps removed, and a small piece of burning waste dropped into the cylinder. The operator then directs a jet of oxygen on the carbon at the point where the waste is burning. This causes the carbon to burn rapidly and to be entirely consumed. By following the burning carbon around the cylinder with the jet of oxygen it will be evenly burned out. Care must be taken to have the cooling system full of water while the carbon is being burned to prevent overheating of the cylinder casting.

When scraping can be conveniently done it is probably the best method but on some engines it is difficult to accomplish without dismantling. The burning out method is also good when done carefully by an experienced operator. The chain method and the use of decarbonizing liquids are not so good. The latter is rather ineffective when the carbon deposit is heavy.

Packing Water Pump Glands. — The water pump glands should be packed with a good grade of waterproof asbestos or compounded packing. If loose twisted asbestos rope is available untwist one strand, soak it thoroughly with cylinder oil, and cover with as much graphite as it will retain. Always coil the packing round the shaft in the direction the packing nut turns when tightened so that it will not tend to unwind when the packing nut is screwed on. The gland nuts should not be tightened any more than is necessary to prevent the leakage of water.

Cleaning the Cooling System. — The cooling system should be flushed with a stream of warm water (if possible) under pressure by forcing it through the system in the reverse direction to which the water flows when the engine is operating. To accomplish this, disconnect the radiator at the lower connection and insert a hose so that the water is forced in at the bottom of the radiator. This should remove all loose dirt and sediment. In case there is a plug in the front of the radiator it may be removed and the water forced in at this point. In this case the lower hose connection to the radiator must be plugged.

After the engine has been used some time and the cooling system refilled a number of times, probably with all kinds of dirty water, a deposit will form on the inside surfaces of the entire cooling system. This prevents proper cooling of the cylinders and of the water in the radiator. To remove this scale dissolve six pounds of washing soda in five gallons of boiling water and pour this into the radiator leaving it in the system while the car operates for a day. Then drain out and flush the cooling system with clean water being careful to refill it with clean water. In addition it is necessary to drain the radiator and refill with fresh water at frequent intervals.

Fuel Feed System. — Gasoline should be strained before it is put into the tank. A wire gauze or chamois strainer can be used in the funnel when pouring the gasoline into the tank. In case chamois is used be sure to keep the funnel in contact with the tank to prevent the generation of dangerous static electricity.

To prevent water from accumulating, the sediment trap when provided and the carburetor should be drained frequently. This is particularly important in winter as the water may freeze and stop up the gasoline line. The carburetor strainer should be removed frequently and cleaned. In most carburetors this is accomplished by loosening a union at the bottom of the carburetor on the feed line after which the carburetor may be removed. In unscrewing the union on the feed line be careful not to unscrew the whole union fitting and twist the gasoline line. Also be sure not to cross the threads in screwing the union back on.

The joints in the air intake manifold should be examined to see that there are no leaks as they are frequently the cause of missing in the engine. When the engine is running these leaks may be detected by putting oil on the suspected spot which will be drawn into the manifold if there is a leak. Shellacking the joints will stop this trouble but when used at the joints above the governor shellac should be applied very sparingly as it may flow down into the

governor and interfere with its action. Blotting paper without shellac may be used for gaskets at these joints.

If on inspection it is found that the carburetor is flooding with the truck standing on level ground the cause may be dirt under the float needle valve or a leaky valve. The small cap on top of the float chamber should be removed exposing the top of the needle valve stem which if lifted or turned may release the dirt causing the leak. If the leak is due to a leaky valve a few **light** taps on the top of the valve stem may cause it to seat properly. Never use grinding compound on this valve as not only the valve but also the seat might be ruined. Further details as to care of the carburetor and the methods of making adjustments will be found in the chapters on carburetors.

Wiring.—All wiring of the starting, lighting, and ignition systems which is exposed should be inspected regularly to see that it is not chafed or rubbed so as to expose the bare wire and cause a ground. The wires may also be broken inside the insulation without giving any indications on the outside. This is most apt to happen where the wire takes a sudden bend or vibrates excessively. Loose connections should be tightened and where a wire is made fast to a terminal it should be soldered. A grounded primary wire on a Ford car may be detected by the constant buzzing of the vibrator on the corresponding coil. The car should not be cranked in this condition as it is very apt to kick back.

Spark Plugs.—These should be examined frequently to see if they are badly carbonized, porcelains broken, and if the points are improperly adjusted or not in good condition. In removing plugs care should be taken not to allow the wrench to slip and break the porcelain of the plug being removed or of the adjacent one. This may be avoided by never using a worn or incorrect sized wrench for this purpose, and by always starting with the right hand plug when removing or replacing them. Plugs when removed may be cleaned with gasoline. If the plug is demountable the porcelain may be removed and the carbon cleaned off with an old tooth brush and gasoline. If it is impossible to remove the porcelain the plug is harder to clean and the carbon may be scraped off the metal parts after being softened with gasoline. A knife or other sharp tool may be used but care must be taken not to scratch the glazed surface of the porcelain as this will cause it to become oil soaked and the carbon will form **readily** on its surface.

The gap between the points of the plug should be between $\frac{1}{32}''$ and $\frac{1}{64}''$. With battery ignition, or on the Ford the gap may be larger than with high tension magneto ignition. Most manufac-

turers of magnetos and ignition systems furnish with their apparatus a wrench or screwdriver with a gauge attached of the proper thickness so that it will just slip between the points of the plug when properly adjusted. As a substitute gauge for battery ignition a worn dime may be used but for magneto ignition the gap should be considerably smaller. This gap should be inspected frequently as the points may pit or wear away causing the gap to become too wide. This will make it difficult to start the engine and may cause the plug to miss fire at low speeds or when pulling hard or accelerating.

The plug should be examined carefully in case it does not fire to see if a porcelain is cracked for this would cause the plug to become short-circuited. The crack may be a fine line crack which is rather difficult to detect. In replacing bad plugs be careful to get the proper type of plug. Not only must the proper thread be used but the plug should also have the proper length as previously explained. When inserting a half-inch plug be careful not to screw it too tightly into a hot engine, for when it reaches the same temperature as the engine it may be difficult to remove the plug.

Distributor. — The distributor cover on a magneto or battery system should be removed regularly to examine the brushes or contacts. The distributor plate should be cleaned with a cloth dipped in gasoline. After cleaning the distributor the rotor or brush track should be given a very fine application of vaseline. If the distributor has brushes be very careful not to lose or damage them in removing the cover. If the car is equipped with a timer and multi-unit coil the timer should be cleaned at frequent intervals with a cloth wet with gasoline.

Interrupters. — Another important part of the magneto or ignition system is the interrupter. The interrupter lever should be examined to see that it is free to move and the gap between the interrupter points should be inspected. To check the adjustment of these points set the interrupter lever on the center of the cam which gives the maximum opening of the points. Then check the gap between them with the gauge supplied for that purpose on the magneto wrench or screwdriver. If this should not be available set the points from 0.015″ to 0.020″ apart using a post card to gauge the distance. This gap should be checked on each cam particularly on those magnetos which have the cams on the interrupter lever housing. If the cams are worn or the housing is worn or distorted the gaps will be unequal. This may be corrected by shimming under the cam which gives the least opening. This work as well as the filing of the breaker points should be done only by

experienced mechanics. If the breaker points are pitted or do not make a good contact it will be necessary to dress the points with a fine file until the surfaces are smooth and make proper contact. The gap should be properly adjusted after the points are filed. The points of a vibrator need the same attention, the proper gap being about $\frac{1}{32}''$ with the spring held all the way down.

Lubrication of Magneto. — In lubricating a magneto follow instructions given as proper lubrication is one of the essential points for satisfactory operation of a magneto or timer-distributor. Too much oil is as bad as too little, since it is apt to get on the windings or breaker points.

Ignition Timing. — To time the magneto first bring number one piston (the one nearest the radiator) to top dead center on compression stroke. This may be done by opening the priming cocks on the other cylinders and turning the engine until compression is felt. The piston is then coming up on compression stroke and if the flywheel is exposed it may be brought to top dead center by checking the marks on the flywheel. If the flywheel is not exposed an approximate method may be used which is close enough to check the setting of the magneto and determine whether faulty timing is the cause of the trouble. Insert a wire or stick through the spark plug hole and turn the engine until this wire stops rising. If this is carefully done the position of top dead center can be located to within about five degrees. If it is necessary to connect up the magneto by this method, it is best to continue turning the engine after the piston reaches the top of its stroke until is just starts to move downward again. This will prevent timing the magneto too early which might cause the engine to kick back when being cranked. However, the magneto should never be set by this approximate method except in case of an emergency.

With the engine set at top dead center the magneto should be turned until the distributor contact is opposite the brush to number one cylinder. Then set so that the contact points are just about to open with the spark retarded. The magneto should be turned in the direction of rotation in making this adjustment. Some magnetos are marked on the distributor plate with a line and an L or R depending on the direction of rotation of the magneto. This mark is so located that it comes opposite a marking pin just as the contact points open, with the distributor contact opposite the lead to number one cylinder. This simplifies the checking of the timing considerably when the breaker box is inaccessible. After timing the magneto to the engine connect the coupling between them. After the two are connected check the setting to make sure nothing was

displaced while tightening the coupling. Observe which way the distributor rotates and connect the leads from the distributor so that each cylinder receives the spark in the proper firing order.

A timer-distributor on a battery ignition system is timed in practically the same manner. Bring number one piston to top dead center on compression stroke as before, but continue to turn the engine until the exhaust valve on the other cylinder which is on top center (number 4 on a four cylinder engine or number 6 on a six cylinder engine) just closes. Loosen the breaker cam adjusting screw on the vertical shaft and set the breaker points so they just start to open with the spark fully retarded. The rotor must also be in such a position that the distributor makes contact with the segment for number one cylinder. The breaker cam must be set carefully so that the points will open and close as the slack in the distributor gears is taken up first in one direction and then in the other. Tighten the adjusting screw and after replacing the rotor connect the leads to the plugs as in the case of the magneto.

To time the " commutator " on the Ford bring number one piston to top dead center on compression stroke as before. As the cylinder head must be removed to properly time the " commutator " the method given above for determining firing position is not applicable. The simplest way to determine this position is by watching the exhaust valve of number four cylinder, for as it closes piston number one will be at top dead center on compression stroke. After reaching top dead center continue to turn the engine until the piston has traveled $\frac{1}{8}''$ on the downward stroke. Set the " commutator " in the full retarded position and place the roller so that it is just starting to make contact with number one segment. Connect up the primary wires so that the spark occurs in the proper cylinder. It must be remembered that the firing order of the Ford is 1–2–4–3, which is different from most four-cylinder engines.

Clutch Adjustments. — If the clutch slips before adjusting the clutch spring make sure that the clutch pedal is not striking the floor boards or that some other obstruction is not preventing the clutch spring from forcing the friction surfaces together. When it is necessary to adjust the spring tension this is accomplished by moving the adjusting nut provided for that purpose. After the adjustment has been made make sure the nut is securely locked in place.

If the clutch has a clutch brake see that it is properly adjusted. This brake should be so adjusted that it takes effect only at the extreme outward position of the clutch pedal. Common clutch troubles and their remedies are covered in chapter XXIII.

Wheel Alignment. — The method of aligning wheels depends upon whether the vehicle is steered by two or all four wheels. On a two-wheel steered vehicle a simple method is as follows: Turn the steering wheel until the right front wheel is in line with the right rear wheel. To determine this a piece of string may be stretched along the outside of the right wheels touching both the front and rear edges of both wheels lightly or they may be aligned by the eye. With the wheels set in this position test the front wheels for "gather" or " toeing in " by sighting along the inner edge of the left front wheel. If properly adjusted an inch to an inch and a half of the rear wheel will be visible which is approximately one-quarter of an inch " gather." If more or less of the rear wheel is visible the tie rod should be adjusted.

With a four-wheel steered vehicle both sets of wheels should be set to " toe in " and the simplest way is to measure the amount of difference in distance between the edges of the front and rear of the wheels with a stick when they are set approximately parallel with the frame.

To determine the amount of " gather " by these methods it is necessary for the wheels to run true. This may be determined by jacking them up one at a time and spinning them. If not true a wooden wheel may be trued up as follows: Hold a piece of chalk against the side of the spinning wheel to indicate where the wheel is distorted. Cardboard shims may now be placed between the spokes and inner hup plate where necessary to make the wheel run true. When demountable rims are used do not confuse the improper setting of the rim bolts causing the tire to run out of true with a wheel out of true. Both should be avoided as they cause undue wear on the tires.

Steering Gear. — While the wheel is jacked up it should be tested for play in the wheel bearings, steering knuckle, and also tie rod or the drag link. This play should be taken up at once if possible. Lost motion in the steering gear should be taken up as soon as it is discovered if an adjustment for this purpose is provided. In some constructions the steering arm is actuated by a short shaft with a square end on which the arm fits. Lost motion often occurs at this point and the steering arm should be inspected and clamped tightly on the shaft if any movement occurs between them.

Brake Adjustment. — Before adjusting the brakes make sure that the cause of their failure to work is not due to oil or grease on the linings. If this is the case make sure that the grease or oil is thoroughly removed with kerosene. It will probably be necessary in case of a wheel brake to remove the wheel to do this properly and

to remove the brake band in case of a transmission brake. If the brake band is clean and does not need replacement it is ready for adjustment. In a transmission brake there are usually two places for adjustment, at the brake adjusting screw to allow for wear of the brake band and on the brake rods to adjust the position of the brake pedal. Wheel brakes usually have another adjustment to obtain equal pull from the equalizer.

In adjusting any brake be sure to observe the following points:

First, make sure that the brake lining clears the drum all around by a small and approximately equal amount with the brake pedal in the fully released position. This adjustment can usually be made with the adjusting screws on the brake and by the brake band supports.

Second, with the pedal approximately one-third depressed the lining should make uniform contact throughout its entire surface with the brake drum. This may be accomplished by adjusting the brake rods and the brake adjusting screws making sure in case of wheel brakes that all take hold at the same time.

If these adjustments are properly made the service brake should lock the wheels with the car running light when the brake pedal is two-thirds depressed. If the brakes grab or screech, a few drops of castor oil or light mineral oil may stop the trouble.

Springs. — In addition to spring lubrication it is important that the spring clips be properly adjusted. The clips themselves should be examined to see that they are not broken and that they fit snugly to the leaves. The bolts should be kept tight but not so tight as to cause the tops of the clips, to be bent in over the top of the spring pinching it and causing either the spring or clip to break. The spring saddle bolts should be inspected frequently to see that they are not loose.

CHAPTER XXXII

CARE AND ADJUSTMENT TABLES

A systematic method of attention at definite intervals is necessary to keep motor vehicles operating satisfactorily. Lack of attention does not show immediately often resulting in certain parts being neglected when unsystematic methods are used.

Lubrication, adjustment, and inspection should be done at regular intervals rather than on a mileage basis. Particularly when the apparatus, such as trucks or cars used for commercial purposes, is in continuous use. However, common sense must be used to prevent under or over lubrication when a vehicle is used more than usual or very little. In this case it is best to go back to the mileage basis. It is a popular misconception, particularly among chauffeurs, that lubrication is over-emphasized. To illustrate the method of making systematic inspection, on the basis of daily, weekly, and monthly attention, a table is worked out for the Dodge and Ford cars, as well as F. W. D. and Nash trucks.

A very important point in the care of a car and one strongly emphasized in the French army is the inspection of motor vehicles on the road. During the first hour's running most of the troubles which will occur have started to develop and an inspection for leaks and loose parts as outlined in Table I made at this time may save serious trouble later. A few moments spent in this manner reduces to a minimum the loss of time which occurs due to breakdowns and also keeps down the repair expenses. This will be particularly true of trucks when the apparatus is used continually.

If all garages or truck and car owners would make out a chart as shown in Table 6 for each particular car, they could keep an exact record of the oil and gasoline used and have a record of the systematic method used to keep the car in proper running order. The only addition needed to make this table complete is to consult the manufacturers lubrication chart and list separately each part to be lubricated just as is done in the table for the other cars and trucks. Use the same checking system as used for the care of the car.

Table 1

ROAD INSPECTION FOR TRUCKS

1. Before leaving the garage in the morning the oil level in the crank case should be examined, the radiator filled with soft water, and the gasoline tank examined to see if there is sufficient gasoline. Run the engine until warm before starting the car, meanwhile looking for gasoline, oil, or water leaks. It is especially important to have the engine warm before starting the car in cold weather.
2. As soon as the car is started test the steering mechanism and brakes for proper operation, and correct any troubles. Listen carefully for unusual sounds and locate their causes.
3. After running for about an hour stop the car and examine as follows:

   A. Let the engine idle and lift the hood.
   Inspect fan belt for tension and bearings for overheating.
   Examine engine for compression leaks around valve caps and plugs.
   Look for air leaks around carburetor and intake manifold.
   Feel pipe at water pump to see if pump is operating properly.
   Examine magneto and cables for loose connections.
   If oil pump can be tested by opening pet cocks do so.

   B. Feel brake drums to see if they are hot due to dragging brakes.
   Inspect springs for loose clips and shifted or broken leaves.
   Note any leakage of oil from differential, axles, or wheels.
   If the wheels have grease plugs examine to see if tight.
   Examine hub caps, universal joints, housing, and grease cup caps to see if secure.

   C. Note any oil leaks from transmission, universal joints, or clutch and if the car has a transmission brake, examine for heat due to brake band dragging.

   D. Examine ground under engine for oil or water dropping from leaks.
   If engine has external oil pump look for oil leaks at pump and tubing.
   Have some one turn steering wheel and examine all steering mechanism, particularly drag links and tie rods for loose connections.

4. This inspection should be very carefully made if the car has just returned from the repair shop, as defects which may not be noticed in the shop will develop when the engine becomes thoroughly "warmed up."
5. On returning to the garage, fill with gasoline and carry out the daily attention prescribed herein for the particular car.

In cold weather drain all water from the cooling system and suspend a tag marked "Drained" from the filler cap. This must **always** be done when the system is drained.

Table 2

DODGE CARS

Daily Attention

A. The oil level indicator rod should be examined and enough medium grade cylinder oil should be added to bring the top of the rod to within ½″ of the waterjacket. The oil should never be allowed to fall so low that the top of the rod is within ½″ of the lower casting.

B. Turn the following grease cups and refill when necessary with cup grease:
   1. Clutch release grease cup.
   3. Engine fan shaft grease cup.
   3. Steering gear tie rod grease cups.
   4. Spring bolt grease cups.
   5. Steering gear worm wheel shaft grease cup.
   6. Steering gear drag link grease cups.

C. Turn up water pump grease cups and refill every 100 miles.

D. Examine tires and see that they are properly inflated.

Weekly Attention

A. With cup grease:
   1. Pack the steering gear drag link.
   2. Remove plug and fill universal joint housing.

B. With cylinder oil (medium) fill:
   1. Rear spring seat strap oil cups.
   2. Brake operating shaft oilers.
   3. Steering knuckle bolt oil cups.

C. Put a few drops of cylinder oil in:
1. Steering wheel oil hole.
2. Brake equalizer clevis pins.
3. All brake pull rods and yoke clevis pins.
4. Brake operating shaft oilers.
5. Hand brake lever latch rod and button.
6. Accelerator pedal shaft brackets.
7. Spark and throttle rod ball and socket joints.
8. Brake pedal.
9. Clutch pedal shaft oil holes.

D. Clean thoroughly engine, running gear, and body, carefully wiping off all excess oil and grease.

E. Test the specific gravity in each cell of the storage battery with a hydrometer. If the specific gravity is below 1.200 the battery needs attention.

After testing fill with distilled water until the liquid stands ½″ above the plates. Do not fill too full and do not add anything but distilled water.

F. Inspect engine.
1. See that wiring connections are tight and clean.
2. Remove, clean, and adjust the spark plugs.
3. Clean the distributor plate with a dry rag and apply a very small amount of vaseline to the distributor track (250 miles).
4. While engine is running inspect water pump packing and grease cups for leaks.
5. Listen to the engine when running for loose bearings or noisy timing gears.
6. Make sure that the oil pump case cover is securely attached and that there is no leak through the gasket.
7. See that the oil gauge registers properly when the engine is running.
8. Test for compression in each cylinder, by turning the engine over by hand, and locate cause if compression is weak.
9. Inject a tablespoonful of kerosene in each cylinder through the pet cocks while the engine is hot and let it stand over night to loosen the carbon in the cylinder.

G. Inspect cooling system.
1. Look for leaks in radiator and hose.

2. See that the fan belt rides evenly and that it has the proper tension.
3. Drain radiator and refill with fresh water.

H. Inspect gasoline line and carburetor for leaks and clean the strainer.

I. Examine brake bands to see that they are not dragging or binding or that oil is not leaking on them from the rear axle. Wipe off the brake drums with kerosene if they are oily.

J. Test front wheels for alignment and see if rear wheels track front wheels.

K. Inspect springs to see that spring clips are tight and that the leaves have not shifted.

L. Examine tires for cuts, stone bruising, sand blisters, etc. Test air pressure with tire gauge.

M. Note during week all body squeaks, rattles, etc., and remedy by tightening bolts. Inspect car thoroughly for loose bolts, etc.

Monthly Attention

A. Remove oil strainer from breather pipe and clean and drain oil from crank case (1000 miles).
Remove blow-out plug at rear end of distributing oil tube in the interior of the crank case and disconnect oil tube at the pump. Blow through this pipe to clean it out. Every other month remove oil strainer at bottom of crank case and clean (2000 miles). Before replacing strainer wash out pan with kerosene poured in through the breather tube. Turn engine over rapidly by hand or starter to remove remaining kerosene. Replace strainer, reconnect oil tube, and refill crank case with six quarts of cylinder oil (medium). When engine is running examine exposed oil pipes for leaks.

B. Make sure that the valves have the proper clearance (0.004″) and set those that have not by adjusting the valve tappet adjusting screws.

C. The wiring of the starting, lighting, and ignition systems should be inspected carefully to see that all terminal connections are tight and that the insulation has not been

chafed or rubbed off to cause a short circuit. Put four or five drops of cylinder oil (medium) in distributor bearing oil well.

D. Remove the plug in the lower end of the steering gear housing and fill with cup grease. Also put several drops of cylinder oil (medium) in the spring oiler at the top of the column.

E. Inspect level of oil in the transmission which should be kept up to the idler gear. Every three months (2500 miles) drain the transmission, wash with kerosene, and refill with five pints of transmission oil.

F. Remove clutch inspection plate and examine clutch release grease tube and clutch operation and alignment.

G. Remove upper and lower plug from differential housing and fill with steam cylinder or transmission oil until it runs out of the lower plug. Drain, clean with kerosene oil, and refill with oil every three months.

H. Remove wheels, clean bearings, and repack with grease every two months, packing the front wheels one month and the rear wheels the next.

I. Lubricate between the spring leaves every two months with grease and graphite.

J. Examine the chassis for loose bolts or other loose parts, particularly in the following places:
   1. Universal joint ring and yokes.
   2. Transmission arm bolts.
   3. Front motor support bolts.
   4. Oil pan and transmission bolts.

Table 3

FORD CARS

Daily Attention

A. The crank case should be filled with cylinder oil (medium) until it runs out of the upper pet cock. The oil must at all times be kept above the level of the lower pet cock.

B. Turn the following grease cups and refill when necessary with cup grease:

1. Fan grease cup, several turns.
2. Rear axle roller bearing grease cup, all the way down.

C. Put a few drops of cylinder oil (medium) in the following places:
1. Commutator.
2. Front and rear spring hangers.
3. Spindle arm and spindle body bolts.
4. Ball joints on steering connecting rod.

D. Inspect and test:
1. Brakes, and adjust if necessary.
2. Tires for proper inflation.
3. Tighten loose nuts and wiring terminals.
4. Springs for breakage.
5. Wheel alignment and all steering connections.

Weekly Attention

A. Examine car for gasoline, water, or oil leaks.

B. Wash and polish car.

C. Clean the outside of engine and crank case thoroughly.

D. Wipe off any oil or grease on fan belt and adjust or replace same if necessary.

E. Jack up front end of car and try for excessive lateral play in wheels, adjusting the bearings when necessary.

F. Test alignment of front wheels and adjust if necessary.

G. Inspect steering system thoroughly.

H. Adjust foot pedals.

I. Equalize and adjust emergency brakes.

J. Tighten all loose bolts.

K. Tighten all loose connections in the ignition system.

L. Oil the following parts with a few drops of cylinder oil (medium):
1. Starting crank handle.
2. Ball and socket joints on spark control lever.
3. Hand brake lever pawl and lift handle.
4. Controller shaft brackets.

5. Speed lever on controller shaft.
6. Brake rod clevis pins.
7. Brake rod supports.
8. Emergency brake shoe cam shafts.

M. Turn the following grease cups and refill when necessary with cup grease:
1. Steering post bracket grease cup, two turns.
2. Universal ball joint grease cup, turn down and refill twice.
3. Drive shaft housing grease cup front end, two turns.

N. Examine spark plugs, clean and adjust gaps.

O. Fill front hub caps with cup grease.

P. Examine tires for cuts and bruises and test for proper inflation.

Q. Drain carburetor and sediment bulb of dirt and water.

Monthly Attention

A. Drain crank case, wash with kerosene, and refill with cylinder oil (medium), (1000 miles).

B. Clean cooling system and examine and repair leaky radiator, faulty connections, and worn out hose.

C. Clean gasoline line.

D. Remove and clean commutator case.

E. Examine commutator roller for too much play and wires for frayed insulation.

F. Examine coil unit.

G. File pitted or uneven points and adjust same to a gap of $\frac{1}{32}$ an inch when springs are carefully depressed.

H. Remove and clean magneto contact plug on top of transmission cover and see that contact points are at the end of the coil spring when replacing the plug.

I. Test for poor compression, leaking cylinder head gasket, loose bearings, and carbon in the cylinders.

J. Remove the steering case cover, pack the case with cup grease.

K. Inspect ball and socket joint at end of steering connecting

rod and eliminate all loose motion by removing and filing down faces of the ball socket caps.

L. Jack up front axle and examine for loose spindle arm and worn spindle body bushings.

M. Examine spring hanger bushing, front and rear, and replace when necessary.

N. Remove front wheel, examine and pack bearings with grease. Inspect stationary and adjusting cones before replacing.

O. Remove front radius rod ball cap and pack with grease.

P. Remove rear hub cap and tighten rear hub lock nuts.

Q. Tighten engine bolts to frame.

R. Grease springs with graphite and cup grease and replace the tie bolts when necessary.

S. Tighten spring clip nuts which hold the front and rear spring to cross members of the frame.

T. Tighten spring retainer clips.

U. Reline transmission bands if necessary.

V. Equalize and adjust emergency brake.

W. Remove plug in rear axle and fill differential housing one-third full of non-fluid transmission lubricant (1000 miles).

Table 4

F. W. D. TRUCKS

Daily Attention

A. The crank case should be filled with cylinder oil (medium) until the oil just runs from the upper pet cock on the crank case with engine stopped and car level. Care must be taken not to put more oil than is just necessary to bring it to this level. Do not depend on the oil gauge to tell you the oil level. Make sure the pet cocks on the crank case are not plugged.

B. A few drops of cylinder oil (medium) should be placed on each of the following places:

1. Outer starting crank bearing.

2. Inner starting crank bearing.
3. Rocker pin bearing on fan belt bracket.
4. Radiator support bearings.
5. The dogs on the gear shift lever and gear shift lever shaft and bearings.
6. All pins on gear shift rods and clutch and brake rods.
7. Clutch pedal and brake pedal bearings.
8. Foot brake bell crank bearings and on pins in foot brake mechanism.
9. Emergency brake equalizer pins and slides.
10 Pins on emergency brake mechanism.
11. Spark and throttle control joints and bearings.
12. Plunger on horn.
13. Shaft inside upper torque rod spring. After lubricating wipe off excess oil.

C. Turn the following grease cups and when necessary fill with cup grease:

1. Fan pulley bearing, several turns.
2. Fan belt drive shaft, several turns.
3. Front spring bolts, one turn.
4. Steering knuckle, four turns.
5. Steering arms, one turn.
6. Clutch shifter shaft and shifter, several turns.
7. Water pump, two turns.
8. Torque rod and arms, one turn.
9. Gear shifter and jackshaft, one turn.
10. Rear springs bolts, one turn.

D. Turn down grease cups on upper propeller shaft universal joints two turns every other day.

F. Clean, trim, and fill all lamps and acetylene generator.

G. Wipe off magneto and wiring.

Weekly Attention

A. Clean truck thoroughly.

B. Thoroughly clean engine and engine compartment.

C. Remove spark plugs, clean and adjust gaps, and replace; inspect and clean wiring, and clean distributor plate with gasoline.

D. Run the engine, watching for water and oil leaks, unusual sounds and loose parts; examine for air leaks around inlet manifold and carburetor.

E. When engine is hot stop and test compression by turning over by hand.

F. While the engine is hot inject a tablespoonful of kerosene in each cylinder through the pet cocks and let stand overnight to loosen the carbon.

G. Turn clutch so that one filling plug is on top. Remove plug and turn engine $\frac{1}{3}$ revolution until next plug is on top. Remove this plug and add a mixture of cylinder oil (medium) and kerosene till it runs out of the lower open plug. Replace the plugs. The proportions of oil and kerosene vary from two parts kerosene to one of oil in cold weather to one part kerosene to two of oil in hot weather. Inspect the clutch pedal to see that it does not strike floor board when the clutch is engaged. Adjust clutch brake if necessary.

H. Pack lower propeller shaft universal joints with grease.

I. Tighten bolts on alignment joint.

J. Tighten spring clip nuts and inspect springs for shifted or broken spring leaves.

K. Inspect wheels for alignment, play, and tighten grease plugs. Inspect tires for cuts and see that rim bolts are tight.

L. Inspect brake bands and see that they are free from oil and do not drag on the drums.

M. Take up all play on torsion rod springs.

N. Drain radiator and refill with fresh water. See that fan belt is free from grease and has proper tension.

O. Pack ball joints on drag link with grease.

Bi-weekly Attention

A. On the Eiseman Type G4 Edition II Magneto, 20 drops of light oil ("3 in 1") should be distributed as follows (500 miles):

1. Oil hole on breaker box, 1 drop.

2. Small hole at driving end, 5 drops.
3. Large hole at driving end, 14 drops.

B. Inspect transmission and subtransmission. Level in transmission should be just above top of countershaft. If below add transmission oil to bring it to the required level. Drain the subtransmission which should contain six quarts of transmission oil. Add enough to the oil drained out to make up the six quarts and replace. Every three months the transmission and subtransmission should be drained, washed with kerosene, and refilled.

C. Fill the foot brake drum with grease through the plug in the cap on the rear of the drum. Remove cap and clean bearings every three months.

D. Check valve clearance adjusting if necessary (intake .004," exhaust .006").

Monthly Attention

A. Examine interrupter points on magneto, smoothing and adjusting if necessary. Examine control connections and check timing of magneto.

B. Drain carburetor, gasoline tank, and piping to remove dirt and water.

C. Drain crank case, flush with kerosene, remove lower half of crank case, clean, and refill with six quarts of cylinder oil (medium). While crank case is off inspect bearings for looseness (100 miles).

D. Put four ounces of cylinder oil (medium) in governor.

E. Repack alignment joint with grease.

F. Fill front and rear axle housing with grease through plug holes. Every three months, drain housing, wash with kerosene, and refill with grease.

G. Fill wheel bearings with grease through plug in hub.

H. Lift spring retained cover on top of steering column and inject $\frac{1}{2}$ pint of transmission oil.

I. Every two months grease the spring leaves with grease and graphite.

Table 5

NASH QUAD TRUCKS

Daily Attention

A. The crank case should be filled with cylinder oil (medium) until the indicator rod on the left side of the engine reads $2\frac{1}{4}$ gal.

B. Turn the following grease cups and when necessary refill with cup grease:
1. Steering knuckle grease cups.
2. Water pump grease cups.
3. Clutch grease cups.

C. Put a few drops of cylinder oil (medium) in the following parts:
1. Spring shackle oil holes.
2. Tie rod clevis pins.
3. Clutch, brake, and gear shift mechanism oil holes.
4. Motor support oil holes.
5. Starting crank bearing and dog.

D. Every second day fill propeller shaft universal joints with cup grease.

E. Wipe off magneto, spark plugs, and wiring.

Weekly Attention

A. Clean truck thoroughly.

B. Clean engine and running gear thoroughly.

C. Remove spark plugs, clean and adjust gaps, and replace. Inspect and clean wiring and clean distributor plate with gasoline.

D. Run the engine watching for oil and water leaks, unusual sounds, and loose parts. Examine for air leaks around inlet manifold and carburetor.

E. When engine is hot stop and test for compression by turning over by hand.

F. While hot, inject a tablespoonful of kerosene in each cylinder through the pet cock and allow to stand over night to loosen carbon.

G. Pack the following parts with grease:
1. Fan pulley hub.
2. Drag link boots.
3. Steering column housing.
4. Axle universal joints.

H. Turn the steering tube grease cups and refill when necessary with cup grease.

I. Oil the following parts with cylinder oil (medium):
1. Shifter box and lever.
2. Hand brake shaft.
3. Brake rocker shafts and all joints on brake connections.
4. Transmission support.
5. Steering knuckle brake cam studs.
6. Governor drive gears.
7. Governor (fill chamber weekly and drain monthly).

J. Tighten spring clip nuts and inspect spring for shifted or broken leaves.

K. Inspect wheels for alignment and play. Inspect tires for cuts and see that rim bolts are tight.

L. Inspect brake bands and see that they are free from oil and do not drag on the drums. If oily wash with kerosene.

M. Drain and refill radiator with fresh water.

Bi-weekly Attention

A. On the Eiseman Type G 4 Edition II Magneto, 20 drops of oil should be distributed as follows (500 miles):
1. Oil hole on breaker box, 1 drop.
2. Small hole on driving end, 5 drops.
3. Large hole on driving end, 14 drops.

B. Inspect transmission and add enough transmission oil to fill case half full or to the level of the overflow plug.

C. Fill differential housing with transmission lubricant. If this is too heavy in winter add some cylinder oil till of the right consistency.

Monthly Attention

A. Examine interrupter points on magneto, smoothing and adjusting if necessary. Examine control connections and check timing of magneto.

B. Check valve clearance and adjust if necessary (0.006″ on inlet valves, 0.008″ on exhaust).

C. Drain carburetor, gasoline tank, and piping to remove dirt and water.

D. Drain crank case, flush with kerosene, and refill with cylinder oil.

E. Fill wheel bearings with grease through inner plug in wheel housing.

F. Lubricate internal gears in wheels through outer plugs in wheel housings with transmission lubricant. Do not put in too much as it may leak out on the brake drums.

G. Every two months grease the spring leaves with grease and graphite.

Table 6

SAMPLE TABLE OF CARE AND ADJUSTMENT FOR GARAGES

Daily

	8	9	10	11	12	13
1. Gasoline supply	8 gal.	7 gal.				
2. Oil level crank case	1 pt.	X				
3. Fill up with water	X	X				
4. Inspect tires for proper inflation	X	X				
5. Springs for breakage	X	X				
6. Lubricate as specified by manufacturers	....	....				

WEEKLY

	May			
	1	8	15	22
1. Clean apparatus thoroughly	X	X		
2. Thoroughly clean engine and engine compartment	X	X		
3. Remove spark plugs, clean and adjust gap, and replace	X	X		
4. Inspect and clean wiring	X	X		
5. Clean distributor plate with gasoline	X	X		
6. With engine running check for,				
(a) Water leaks	X	X		
(b) Oil leaks	X	X		
(c) Unusual sounds	X	X		
(d) Loose parts	X	X		
(e) Gasoline line leaks	X	X		
(f) Air leaks around carburetor and intake	X	X		
7. While engine is hot, test compression by turning over by hand	1 G 2 G 3 G 4 F	1 G 2 G 3 F 4 W		
8. While the engine is still hot inject a tablespoonful of kerosene in each cylinder and let stand over night to loosen up carbon	X	X		
9. Drain radiator and refill with soft water	X	X		
10. See that fan belt is free from grease and has proper tension	X	X		
11. Inspect wheels for wheel alignment and play	X	X		
12. Inspect steering apparatus	X	X		
13. Inspect tires for cuts and see if rim bolts are tight	X	X		
14. Inspect brake bands to see if they are free from oil and do not drag on drums; see if they brake equally	X	X		
15. Tighten spring clips and inspect springs for cracked, broken, or shifted spring leaves.	X	X		
16. If car has storage battery, test specific gravity in each cell. If the reading is below 1.020 the battery needs attention. After testing fill with distilled water till the liquid stands ½ inch above plates	X	X		
17. Lubrication as specified by manufacturers	....	....		

Monthly

	May	June	July	Aug
1. Check valve clearance and adjust..........	X			
2. Examine interrupter points on ignition system	X			
3. Examine control connections.............	X			
4. Check timing of ignition.................	X			
5. Check all wiring for loose connection and chaffed wires.......................	X			
6. Drain carburetor, gasoline tank, and piping to remove dirt and water............	X			
7. Clean cooling system....................	X			
8. Test for play in wheel bearings...........	X			
9. Test for play in differential..............	X			
10. Test for play in steering apparatus.........	X			
11. Drain crank case, clean with kerosene, and refill with new oil...................	6 qts.			
12. Lubricate as specified by manufacturers....	....			

INDEX

G

H

I

K

L